ROOTING FROM DIFFERENT PORTION OF STEM CUTTING OF CROTON (*Codiaeum variegatum)* USING DIFFERENT PLANT GROWTH REGULATORS

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CERTIFICATE

This is to certify that thesis entitled, "ROOTING FROM DIFFERENT PORTION OF STEM CUTTING OF CROTON (Codiaeum variegatum) USING DIFFERENT PLANT GROWTH REGULATORS" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (MS) in HORTICULTURE, embodies the result of a piece of bonafide research work carried out by MOORSHIDA PARVIN, ***Registration no.****19-10203 under my supervision and guidance. No part of the thesis has been submitted anywhere for any other degree or diploma.*

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

Dated: December, 2021
Place: Dhaka, Bangladesh

Dr. Mohammad Humayun Kabir
Professor
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DEDICATED

TO

MY BELOVED PARENTS

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ROOTING FROM DIFFERENT PORTION OF STEM CUTTING OF CROTON (*Codiaeum variegatum*) USING DIFFERENT PLANT GROWTH REGULATORS

ABSTRACT

Two field experiments were conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from March-2019 to February-2020 (both Kharif and Rabi seasons) to study the rooting from different portion of stem cutting of croton (*Codiaeum variegatum*) using different plant growth regulators. The experiment consisted of two factors, and followed Randomized Complete Block design (RCBD) with three replications. Factor A. Different portion of stem cuttings denoted as C:C_1=basal portion of the stem, C_2=middle portion of the stem, C_3=top portion of the stem, and factor B: Plant growth regulators denoted as S:S_0=control, S_1=IBA (indole-3-butyric acid) @500 ppm and S_2= NAA (1-naphthaleneacetic acid)@1000 ppm. All of the studied parameters were significantly influenced by different cutting positions. The C_1 portion of stem cuttings had the highest sprouting percentage (98.22 and 95.78%), roots per cutting (8.44 and 4.47), root lengths (5.03 and 2.73 cm), and shoot lengths (11.59 and 8.84 cm) in both Kharif and Rabi seasons, while C_3 portion of stem cutting had the lowest performance of the aforesaid parameters. In the case of different plant growth regulators, S_1 treatment had the highest sprouting percentages (90.22 and 85.78%), roots per cutting (7.40 and 3.91), root length (4.93 and 2.67 cm), and shoot length (11.44 cm) among the various plant growth regulators applied in both Kharif and Rabi seasons. Therefore, it may be concluded that C_1S_1 treatment was better than all other treatments recording the maximum values of various attributes related to the shoot and root growth parameters of croton cuttings during both Kharif and Rabi seasons.

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ABBREVIATIONS AND ACRONYMS

Full word	Abbreviations
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.

CHAPTER I

INTRODUCTION

Ornamental plants are mainly used to enhance the beauty of different locations, e.g. Gardens, homes etc. 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 our economic benefits as those are used in various floral arrangements. Apart from increasing the aesthetic value of the property, these also improve the quality of the space by acting as wind barriers, providing shade, cleaning- up the air pollutants, reducing soil erosion and providing the habitat and food 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 ourselves psychologically and keeps us happy. We can achieve a calm mind and healthy body by indulging in gardening with ornamental plants.

Among different group of ornamental plants, flowering, shrubs, foliage shrubs and climbers, ixora, hibiscus, crape jasmine, croton, Java fig tree, acalypha, bougainvillea, golden shower and clerodendron are the most common ornamental plant species grown in South Asia (Naik*et al*., 2018).

Codiaeum varigatum(croton) is an extensively cultivated flowering plants under the Euphorbiaceae family. It is a genus of lovely ornamental plants known for their attractive colourful foliage. Croton plants with the stiff, leathery leaves in bold colors of yellow, pink, red, orange and green make those beautiful and popular house plants. Croton plants are used as ornamental shrubs and house plants (Chen and Stamps, 2006).

Ornamental plants can be propagated either sexually (by seed) or asexually (by vegetative means). A number of horticultural plants, especially ornamental ones, are propagated commercially by vegetative means. However, many ornamental plants do not normally produce any viable seed at all. On the other hand, this unique characteristic may be deteriorated due to cross pollination when it is propagated through seeds. Among the vegetative means, stem cutting is one of the commercial, easiest, cheapest and least time consuming methods of plant propagation with high percentage of success (Bose and Mukharjee, 1977).

Cutting technique is the widely utilized vegetative method for propagating different plant species. Commercial propagators have developed techniques that successfully manipulate environmental conditions to maximize rooting of cuttings (Guimaraes*et al*., 2019). The success of rooting of cuttings is affected by many factors, such as, the plant part's age and its location on the plant, nutritional levels of the stock plants, seasonal timing, cuttings, types, rooting media, environmental manipulation and hormonal treatments of cuttings as well(Naik*et al*., 2018).

The position of the stem cuttings on the branches also affects rooting since it interferes with both the hormonal and juvenile issues. Apical cuttings have higher rates of auxin synthesis and may be less tissue differentiated, but those are more sensitive to dehydration. Basal stem cuttings, in spite of the lower levels of endogenous auxin, have a greater capacity to provide the necessary reserves for the formation and growth of roots and shoots (Cunha *et al*., 2015). Some plants root better at a particular stage of growth, at a specific time of the year, or using a particular technique. Seasonal timing or the period of the year in which cuttings are taken, could play vital role in rooting of plant species, especially woody ones (Harrison-Murray, 1991). With many plant species, there is an optimal period of the year for taking cutting materials and consequently root initiation (Anand and Haberlein, 1975).

Plant growth regulators, such as, indole-3-butyric acid (IBA), naphthalene acetic acid (NAA) and 6-benzylaminopurine (BAP) are frequently used to promote rooting in cuttings (Hartmann *et al.*, 2002 and Verma, 2012). Auxin induces root formation by breaking root apical dominance induced by cytokinin (Dunsin*et al*., 2016).

Among all the rooting plant growth regulators, auxins are commonly used, like Indole Butyric Acid (IBA), naphthalene Acetic Acid (NAA) and indole acetic Acid (IAA) that are applied in liquid, paste or powder form for promoting rooting of stem cuttings. Cuttings treated with alpha naphthalene acetic acid (NAA) and Indole-3-Butyric Acid (IBA) as plant growth regulators help in early and better rooting with easy establishment of plants in the field (Nisio 1998).Cuttings of some species root easily without auxin application of any, but its application results in better rooting. Performance of auxin application for rooting quality may depend upon several other factors like species, types of cuttings(i.e. softwood, hardwood, semi-hardwood) and time of cutting preparation (Hartmann *et al.*,2002). Several researchers have reported about the optimum concentration of plant growth regulators needed for root induction and development on cuttings for propagation of various crops. Plant growth regulators, such as, IBA and NAA are frequently used to stimulate root induction and development in vegetative propagation, application of root inducing hormones on cuttings facilitate to induce plentiful roots within a short time (Paul and Aditi, 2009). NAA and IBA are useful auxins for this kind of studies for the reason that those display a great extent of flexibility dealing with the range of concentrations, efficiency of IBA is to increase the rooting and survival percentages of rooted cuttings is a striking fact (Verma, 2012).

In croton, the response of different stem cuttings with respect to different plant growth regulators is variable. Therefore, the present study was conducted to ascertain the application of plant growth regulators on root in stem cutting of croton *(Codiaeum variegatum)* during both Kharif and Rabi seasons with the following specific objectives:

i. To evaluate the effect of plant growth regulators on rooting in stem cutting of croton
ii. To determine the rooting performance of different portions of stems of croton
iii. To assess the seasonal rooting performances of croton stem cuttings in response to plant growth regulators
iv. To find out the combined effect of plant growth regulators and different portions of stem cutting of croton on rooting

CHAPTER-II

REVIEW OF LITERATURE

Croton is an extensively grown flowering plant in the spurge family Euphorbiaceae. The plants of this genus were described and introduced to Europeans by Georg Eberhard Rumphius. The common names for this genus are rushfoil and croton, but the latter also refers to *Codiaeum variegatum*. The objective of this "Review of Literature" chapter is to have an in-depth review of the significant works performed in the past and gaining the basic information for conducting and considering the outcome of the present research. So, an attempt was made to collect and study the related information available in the country as well as abroad regarding the “Rooting from different portion of stem cutting of croton using different plant growth regulators”for conducting the current research work is discussed under the headings given below:

2.1 Effects of types of cuttings on the performance of rooting in different plants

Malakar *et al.* (2019) conducted an experiment on the effects of growing media and plant growth regulators on the rooting of different types of stem cuttings in acid-lime cv. Kagzi at Bagalkot, Karnataka, India. They found that significantly the maximum number of leaves (11.03), length of shoot (4.43 cm), rooting percentage (24.44) and minimum days taken for sprouting (24.47) were observed in hardwood cuttings.

Patel and Patel (2018) observed the role of auxins on rooting of different types of cuttings in fig at Anand, Gujarat. They revealed that significantly the maximum shoot length (3.53 and 6.17cm), dry weight of roots (0.32 and 0.41 g), rooting percentages (49.60 and 60.02) at 30 and 60 days after planting, respectively, and the minimum number of days taken for sprouting (20.55) were observed in hardwood cuttings.

Singh *et al.* (2018) studied the root growth of phalsa (*Grewia asiatica*L.) as affected by types of cuttings and rooting media at Kota, Rajasthan, India. They reported that significantly the longest sprout (8.31 cm), number of leaves (7.44), rooting percentage (56.66) and survival percentage (57.77) were observed in hardwood cuttings.

Bhuva (2014) conducted a research on the effects of plant growth regulators on propagation of fig (*Ficuscarica*L.) by hardwood and semi hardwood cuttings at Gujarat, India. He recorded significantly the maximum fresh weight of shoot (4.52 g), dry weight of shoot (2.66 g), fresh weight of roots (1.50 g), dry weight of roots (0.56 g), rooting percentage (81.60), survival percentage (67.96) and the minimum days taken for sprouting (11.41) in hardwood cuttings.

Sivaji *et al.* (2014) studied the effects of types of cutting and IBA concentration on the propagation of fig (*Ficus carica* L.) cv. Poona Fig under open conditions at Andhra Pradesh, India. They argued that significantly the maximum length of root (19.99 cm), number of leaves per cutting (8.10), fresh weight of root (1.49 g), dry weight of root (0.49 g), fresh weight of shoot (38.63 g), dry weight of shoot (13.89 g), rooting percentage (68.48) and survival percentage (80.18) were found in the basal cuttings compared to the middle and the apical cuttings.

Adekola *et al.* (2012) claimed that 60 cm long stem cuttings produced the highest number of sprouts per cutting (10.0) and rooting percentage (73.8) while 30 cm long cuttings had the least number of sprouts (7.0) with the highest mean leaf number of 64 and rooting percentage of 44.2 % in *Jatropa curcus*.

Khapare *et al.* (2012) carried out research on the effects of plant growth regulators on the rooting in cuttings of fig (*Ficus carica* L.) cv. Dinkar at Akola, Maharashtra, India. They depicted that significantly the maximum rooting percentage (52.49) and survival percentage (82.29) were in the hardwood cuttings.

From the study conducted by Severino *et al.* (2011) on the propagation through stem cuttings, they reported that the basal stem cuttings produced highest leaf area of 744.6 cm^2, maximum survival percentage of 83.3, highest shoot dry matter of 10.1 g and root dry matter of 0.47 g compared to the middle and the apical cuttings in *Jatropha curcas*.

Tiago *et al.* (2010) conducted an experiment on *Coffea arabica* L. the propagation by different types of cuttings under different environments. Among all the semi-woody cuttings, the highest root length (16.91cm) was recorded in shaded nursery than in the greenhouse. Semi-woody cuttings recorded the highest total dry matter accumulation (1.62) in shaded nursery compared to those from the greenhouse.

Raveendran *et al.* (2010) claimed that the no. of sprouts, girth of sprout, no. of roots and root length were maximum in basal part of the culm, but medium in middle part of the culm, while the lowest in the apical part of the culm in the bamboo species (*Dendrocalamus giganteas).*

Sharma *et al.* (2009) reported 100% survival of the hardwood and semi-hardwood rooted cuttings of pomegranate cv. Ganesh under field conditions.

Dharshan (2008) conducted an experiment on the propagations through stem cutting and air layering of fig (*Ficusc arica* L.) cultivar 'Poona Fig' at University of Agricultural Sciences, Bangalore, India. He found that significantly the maximum number of leaves per plant (4.92) and rooting percentage (63.20) were in the basal cuttings.

Opuni-Frimpong *et al.* (2008) reported a decrease in the rooting potential of stem cuttings due to increased age of the donor plants which may be due to a decrease in the content of endogenous auxins or accumulation of inhibitory substances which inhibited rooting in two African mahoganies: *Khaya anthotheca*Welw and *Khaya ivorensis*A. Chev.

Reddy *et al.* (2008) investigated that the hard wood cuttings had the maximum survival percentage of 88.33 and the highest root length of 19.05 cm compared to the semi-hardwood cuttings which had 68.88 percent survival and a root the length of 13.58 cm in fig.

Wang (2008) analyzed the cutting of four species of *Picea* spp and concluded that the rooting rate was positively correlated with the cutting length, and hormones used.

Agbo and Obi (2007) observed variations in the rooting ability for cuttings taken from different positions of the shoot. The better result found in the basal position followed by the middle and the top positions in the species *Gongronemalatifolia*Benth.

Mohammed and Jian (2007) carried out an experiment on effects of different auxins and types of cuttings on the rooting ability of orange cv. Local (*Citrus sinensis* L.) cuttings in Kurdistan of Iraq. They depicted that significantly the highest length of shoot (8.03 cm) and rooting percentage (83.66) were in basal cuttings.

Nautiyal *et al.* (2007) found the maximum rooting in the untreated branch cuttings in the Giant bamboo *Dendrocalamus giganteus.*

Das *et al.* (2006) observed the rooting of olive stem cuttings under zero energy environment at Srinagar, Jammu and Kashmir. They revealed that significantly the maximum rooting percentage (83.70) and survival percentage (68.62) were in the hardwood cuttings.

Husen and Pal (2006) found that the rooting ability of tree species through stem cuttings was markedly affected by several factors such as, portion of stem cutting from the shoot, age of the donor plant and IBA treatment. The better result was found in juvenile plant than mature one and basal position cuttings has higher growth rate followed by middle and top positions in *Tectona grandis Linn. F*).

Hossain *et al.* (2006) found that the cutting of *Bambusa vulgaris (bamboo)* started to develop active buds within 7-10 days and produce profuse roots in the propagation beds within 4−8 weeks depending on the season.

Kumar (2006) studied the effects of position of cutting and auxin treatment on the rooting of Allison cultivar of kiwifruit at Abohar, Punjab. He revealed that significantly the maximum survival percentage (83.14) and rooting percentage (47.31) were in the terminal cuttings.

Bhardwaj and Mishra (2005) reported on the effects of age of donor plant on the rooting ability of stem cuttings in many trees that the juvenile plant performed better result than the mature one in the plant marn elm *Ulmusvillosa.*

Elsheikh (2005) had an experiment on the propagation of lime (*Citrus aurantifolia* L.) by stem cutting technique at the University of Khartoum, Sudan. He found significantly the maximum number of leaves (5.94), rooting percentage (71.66) and survival percentage (46.79) in the basal cutting compared to the terminal and the medium ones.

Ganta (2004) studied the effects of growth regulators on the rooting of fig (*Ficus carica*) cuttings under greenhouse and open conditions at University of Agricultural Sciences, Bangalore, India. She reported that significantly the maximum length of shoot (17.50cm), number of leaves per cutting (7) and survival percentage (57) were in the basal cutting.

Husen (2004) found high rooting ability of cuttings taken from the basal position in the plant *Dalbergia sissoo*.

Husen and Pal (2003) studied the influence of different cutting positions from the shoot on the overall quality, rooting ability and subsequent growth habit of rooted stem cuttings and got results best in the basal position followed by middle and top ones in *Tectona grandis* Linn. f.

Zalesny *et al*. (2003) found better rooting of cuttings taken from the basal position followed by cuttings from the middle position than those from the apical position which were potentially associated with the increased carbohydrate storage, initiation of preformed root primordial, and differences in the organogenic activity along the stem of the parental shoot in *Populus Silvae* Genet.

Banik (2000**)** found branch from the base or one node from the main branch and 3-4 nodes from the secondary branches is cut for propagation in *Bambusa. vulgaris var. vittata*.

Hannerz *et al.* (1999) observed that the cutting results of *Picea abies* for the rooting ability of different cutting types (length, diameter, position, age) were significantly different.

Tchoundjeu and Leakey (1996) found that different cutting positions from the shoot influenced the overall quality, rooting ability and subsequent growth habit of rooted stem cuttings in African mahogany.

Malab *et al.* (1995) found that the propagation through branch cuttings was one of the most practical methods and easy to handle. Thick walled species with stout branches like those of *Bambusa* and *Dendrocalamus* species grew much better. Generally, the basal and the middle portions of the bamboo poles were good sources of branch cuttings.

Panwar *et al.* (1994) reported that the higher root length was obtained when bougainvillea cutting were treated with IBA @ 2000 ppm. Hardwood cuttings of bougainvillea showed better root length than those of semi hardwood cuttings.

Shenoy (1992) reported that the basal woody cuttings of Damask rose produced roots better than the middle semi woody cuttings, and application of IBA @ 3000 ppm resulted in the highest survival percent of rooted cuttings (48.97).

Reddy and Singh (1988) experienced that the hardwood cuttings of guava had the highest percent (62.86) of survival under plastic house conditions.

Reddy (1984) claimed that the basal and the terminal cuttings taken from the current seasons growth gave more number of roots of 25.55 and 19.40, respectively, compared to previous seasons growth in grape.

Bose *et al.* (1975) investigated the rooting of woody basal, semi woody middle and less woody tip cuttings of some ornamental plants and reported that the leafy cuttings from the semi woody middle portions had better rooting than those from other types of wood.

Scarborough (1971) argued that the rooting capacity of cuttings was depended on the types of wood, and also the portion of the plant from which those were taken.

2.2 Effect of different plant growth regulator on rooting of cuttings

Malakar*et al.* (2019) found significantly the maximum number of leaves (10.43), length of shoot (4.19 cm) and rooting percentage (21.29) in the cutting treated with IBA@ 500 ppm.

Aghera and Makwana (2018) studied the effects of IBA concentrations and the types of media on the rooting and survival of cutting in fig (*Ficu scarica* L.) cv. Poona Fig at Gujarat, India. They pointed out that the cutting treated with IBA @ 2000 ppm gave significantly the maximum fresh weight of root (2.82 g), dry weight of roots (1.84 g), rooting percentage (75.98) and survival percentage (75.98).

Ahmed *et al.* (2018) conducted an experiment on the effects of IBA and GA_3 on Rangpur lime (*Citrus limonia* Osbeck) at Allahabad, Uttar Pradesh, India. They found that IBA

@1000 ppm gave significantly the maximum percentage of root per cutting (45.37), survival percentage of rooted cutting (60.00) and number of leaves per cutting (2.27).

Ayesh and Thippesha (2018) studied the influences of plant growth regulators on the rooting of the stem cuttings in dragon fruit [*Hylocereus undatus* (Haworth) Britton and Rose] at Shivamogga, Karnataka, India. They observed that the stem cutting treated with 7000 ppm IBA showed significantly the maximum fresh weights of root (0.46, 1.87 and 2.28 g), dry weights of roots (0.25, 0.46 and 0.67 g) and rooting percentage (33.66) at 30, 60 and 90 days after planting.

Devana (2018) conducted an experiment to compare the effects of plant hormones and bio-fertilizers on the stem cutting propagation of mulberry (*Morus alba*) at Raipur, Chhattisgarh. She found that significantly the minimum days were taken to start sprouting (7.17), maximum number of leaves per cutting (10.07) and fresh weight of roots (3.02 g) were recorded under the treatment of IBA @ 2000 ppm.

Dahale *et al.* (2018) studied the effects of plant growth regulators on the rooting and survival of hardwood cuttings in fig at Akola, Maharashtra, India. They concluded that significantly the maximum length of shoot (11.46 cm), number of leaves (7.20), rooting percentage (58.66) and survival percentage (82.50) were in the cuttings treated with IBA @ 1000 ppm + NAA @1000 ppm.

Hakim *et al.* (2018) observed the influence of bio-fertilizer and auxin on the growth and rooting of pomegranate (*Punica granatum* L.) cutting at Bangalore, Karnataka, India. They revealed that the length of the longest shoots (39.73 and 41.53 cm), numbers of leaves (41.67 and 44.60), fresh weights of shoots (10.80 and 12.60 g), dry weights of shoots (5.80 and 6.60 g), fresh weights of roots (2.56 and 2.75 g) and dry weights of roots (1.62 and 1.85 g) were significantly maximum in both the cvs. Bhagwa and Ruby, respectively, with the application of IBA@ 1500 ppm + NAA @1500 ppm + Biomix.

Kaur *et al.* (2018) studied the role of IBA and PHB on the success of cuttings of fig cv. Brown Turkey at Amritsar, Punjab, India. They recorded that IBA@ 3000 ppm gave significantly higher shoot length (16.2 cm), fresh weight of shoots (52.39 g), dry weight of shoot (20.35 g), number of leaves (17.08), fresh weight of roots (1.86 g), dry weight of roots (0.70 g), rooting percentage (71.10), survival percentage (73.33) but the minimum days to sprouting (13.66).

Kuntagol *et al.* (2018) investigated the effects of IBA and NAA on the root parameters of hardwood cuttings of fig varieties at Bagalkot, Karnataka, India. They recorded that significantly maximum rooting percentage (36.22) and survival percentage (86.52) with IBA @3000 ppm.

Mehta *et al.* (2018) studied the effects of IBA concentration and time of planting on rooting in pomegranate (*Punica granatum*) cutting at Kota, Rajasthan, India. They found significantly higher number of sprouted cutting (7.73), length of longest sprouts (7.28 cm), number of leaves on new shoots (10.66) and percentage of rooted cutting (73.33) under IBA 500@ ppm treatment.

Patel and Patel (2018) observed that the cutting treated with IBA@ 4000 ppm gain significantly higher shoot lengths (5.01 cm, 8.36 cm), dry weights of root (0.56 g, 0.73 g) and rooting percentages (58.96, 73.24) at 30 and 60 days after planting but too minimum number of days for sprouting (18.07).

Akram*et al*. (2017) studied clonal multiplication of guava (*Psidium guajava*) through soft wood cuttings using IBA under low-plastic tunnel. Guava softwood cuttings were treated with 0, 200, 400 and 600 ppm. The highest number of roots and root length were observed in the cutting treated with 400 ppm IBA solution in the sand, and which the lowest in the cuttings without IBA treatment in sand media.

Ghosh *et al.* (2017) studied the efficacy of different levels of IBA and NAA on the rooting of phalsa (*Grewia asiatica* L.) cutting at Nadia, West Bengal. They reported significantly higher number of leaves (9.23), fresh weight of shoot (18.75 g), dry weight of shoot (9.98 g), fresh weight of roots (3.37 g), dry weight of roots (0.98 g), rooting percentage (70.55), and survival percentage (37.82) were noted but the minimum days were taken for sprouting (9.79) in cutting treated with IBA @200 ppm.

Kamboj *et al.* (2017) investigated the effects of indole butyric acid on the rooting and vegetative parameters of pomegranate (*Punica granatum* L.) In that study, the 15 cm long cuttings were taken and treated with three levels of IBA, i.e. 100, 500 and 1000 ppm. The cuttings were planted in February and the cuttings were studied after 90 and 120 days of plantings. The results revealed that the maximum average stem diameter, leaf number, roots number per plant, root length and root weight were observed in the cuttings treated with IBA@ 1000 ppm.

Muttaleb *et al.* (2017) compared the rooting of stem cuttings with different IBA treatments and development of micro propagation protocol for *Piper betle* L. node culture The cutting were treated with different IBA concentrations of (0, 500, 1000, 1500 and 2000 ppm). The best results, however, was with2000 ppm IBA in the semi hardwood cuttings, with maximum number roots (35.05), fresh weight roots (3.94 g), the dry weight roots (0.33 g), length roots (391.88 cm), the roots diameter (1.21 mm) the surface area of the roots (121.83 cm^2) and the root volume (2.99 cm^3).

Patel *et al*. (2017) studied the effects of different levels of IBA and NAA on the rooting of hardwood and semi-hardwood cuttings of fig. The highest percentage of rooting, maximum number of roots, longest root per cutting and maximum survival percentage of rooted cuttings were obtained with IBA @ 4000 ppm followed by IBA @ 2000 ppm in hardwood cuttings. Among the different levels of IBA and NAA, IBA @ 4000 ppm resulted the maximum root length, survival percentage and other shoot characteristic compared to the rest of the treatments.

Rosimeri *et al.* (2017) conducted an experiment on the maximum efficiency of concentrations of IBA in promoting the rooting of Japanese flowering cherry. There was a gradual increase in the rooting percentage with the increment of IBA to the approximate concentration of 2700 ppm with results higher than 80 per cent.

Singh (2017) conducted an experiment on the effects of IBA concentrations on the rooting of pomegranate (*Punica granatum* L.) cv. Ganesh hardwood cuttings under mist house conditions. The stem cuttings were treated with IBA solutions of different concentrations, i.e. 1, 2, 3, 4, 5 g/L and control by the quick dip method. Among all the treatments, the maximum number of sprouted cuttings (7.33), average length of sprout (20.53 cm), average number of leaves (25.33), percentage of rooted cutting (73.33), number of primary roots (29.26), and average length of roots (24.88 cm) was noticed in 5 g/L concentration of IBA.

Sajad *et al.* (2016) set an experiment on the effects of plant growth regulators on the rooting of apple root stock MM106 cutting at the Central Institute of Temperate Horticulture, Jammu and Kashmir. They revealed that cutting treated with 1000 ppm IBA showed significantly the highest number of leaves per cutting (2.27), rooting percentage (47.29) and survival percentage (60) as well.

Singh and Bahadur (2015) worked on the effects of NAA and IBA on rooting and establishment of hardwood cuttings in phalsa (*Grewia subinaequalis*L.) at Allahabad, Uttar Pradesh. They recorded significantly the maximum shoot length (22.67 cm), rooting percentage (75) but the minimum days to first sprouting (4) in cutting treated with IBA@400 ppm + NAA @ 200 ppm.

Raut *et al.* (2015) evaluated the effects of IBA and different rooting media on the pomegranate cutting at Akola, Maharashtra. They reported that significantly the maximum length of shoot (54.58), number of leaves per cutting (115.33), survival percentage (63.33) but the minimum days were taken for sprouting (17.27) in IBA @ 2500 ppm.

Sulaiman and Abdul (2015) conducted an experiment on the effects of cutting types and IBA on the rooting and growth of citron (*Citrus medica* L.) cv. Corsian at the University of Duhok, Iraq. They found that the cutting treated with IBA @ 1000 ppm give significantly the highest length of shoot (16.55 cm), number of leaves (12.72) and rooting percentage (93.33) as well.

Vivek *et al.* (2015) studied the effects of different doses of IBA and rooting media on the rooting of stem cuttings of lemon (*Citrus limon* Burm) cv. Pant Lemon at Meerut, Uttar Pradesh. They depicted that 800 ppm IBA + garden soil + sand + vermicompost gave significantly the maximum number of leaves per cutting (14), survival percentage (88.70) while the minimum days were needed taken for sprouting (6).

Bhuva (2014) recorded significantly the maximum fresh weight of shoot (4.64 g), dry weight of shoot (2.62 g), fresh weight of roots (1.57 g), dry weight of root (0.66 g), rooting percentage (82.26), survival percentage (74.95) but the minimum days were taken for sprouting (11.38) in the cutting treated with IBA @ 2000 ppm.

Singh *et al.* (2014) conducted a trial on the effects of various concentrations of IBA and NAA on the rooting of stem cuttings of mulberry (*Morus alba* L.) under mist house conditions in Garhwal Hill Region of Jammu and Kashmir. They revealed that IBA @ 2000 ppm resulted significantly the highest average length of sprout (15.27 cm), average number of leaves per cutting (7.67) and rooting percentage (96.67) too.

Sivaji *et al.* (2014) experienced that significantly the highest shoot length (16.82 cm), number of leaves per cutting (8.58), fresh weight of shoot (42.67 g), dry weight of shoot (12.98 g), rooting percentage (69.71), survival percentage (83.84) and the minimum days were taken to first sprouting (11.30) were observed in cuttings treated with IBA @ 3000 ppm.

Adekola *et al.* (2012) reported the highest survival percentage of 66.8 in 30 cm stem cuttings when compared to 60 cm cuttings of 23.8 % treated with IBA @ 150 ppm in *Jatropa curcas*.

Egbe *et al.* (2012) observed the longest roots length of 1.23, 2.48 and 1.48 cm in leafy stem cuttings of albizia, blighia and lophira respectively when treated with IBA @ 1600 ppm under shade house condition.

Khapare *et al.* (2012) depicted that significantly the maximum rooting percentage (62.50) and survival percentage (89.73) were in the cuttings treated with IBA @ 2500 ppm + NAA @ 2500 ppm.

An experiment was set by Bhatt and Tomar (2011) on the propagation of kagzi-lime through semi-hardwood cuttings under different environmental conditions. They recorded the maximum number of leaves of 14.33 in the cuttings treated with 500 ppm IBA under poly house conditions, 7.00 number of leaves under partial shade conditions and 6.33 number of leaves under open conditions.

Sulusoglu and Cavasoglu (2010) conducted an experiment on 16 types of cherry laurel with semi hardwood cuttings for rooting with IBA at different concentrations. The longest root length of 9.24 cm was recorded in the cuttings treated with 2 g/l compared to other treatments of IBA.

Deb *et al.* (2009) observed that the semi hardwood cuttings of lemon gave the maximum root dry weight of 1.48 g and shoot dry weight of 22.73 g when treated with 2500 ppm IBA under Calcutta conditions.

Sharma *et al.* (2009) revealed that the semi hardwood and the hardwood cuttings of promegranate cv. Ganesh treated with IBA @ 500 ppm + Borax @ 1% produced the maximum root numbers of 16.47 and 27.12 in the semi-hardwood and the hardwood cuttings while the cuttings treated with IBA @500 ppm + Boron 1%, IBA 300 ppm +Borax 2% and IBA 5000 ppm gave 100% survival of the rooted cuttings under field conditions.

Dharshan (2008) found that the stem cuttings treated with IBA @ 1000 ppm produced significantly the highest number of leaves per plant (5.65), and sprout length (19.72 mm) and rooting percentage (66) at 60 DAS.

Kumar *et al.* (2008) studied the propagation of passion fruit cv. Kaveri by cutting under coorg conditions. They observed that the cuttings treated with 800 ppm NAA had significantly the maximum fresh weight (2.38 g) and dry weight of roots (0.43 g).

Jadhav (2007) reported that the stem cuttings treated with 200 ppm IBA resulted early sprouting in 14 days, highest rooting percentage of 70.00, maximum survival percentage of 60, highest root length of 32.16 cm and maximum root number (41.67) in phalsa.

Mohammed and Jian (2007) depicted that significantly the maximum rooting percentage (73.66) was observed under IBA @ 200 ppm.

Singh *et al.* (2007) had an experiment on the influence of planting time and IBA on the rooting and growth of pomegranate (*Punica granatum* L.) ‘Ganesh’ cutting at Amritsar, Punjab. They depicted that significantly the maximum survival percentage (90.96) was in the cuttings treated with IBA @ 2000 ppm.

Siddiqui and Hussain (2007) observed the effects of indole butyric acid and types of cuttings on the root initiation of *Ficus Hawaii* at Peshawar. They argued that the cuttings treated with IBA @ 4000 ppm gave significantly the minimum (18) days required for root initiation and highest number of leaves per plant (63).

Upadhyay and Badyal (2007) observed in pomegranate that, the maximum survival percentage of 81.33was in the hardwood cuttings treated with IBA @ 2000 ppm closely followed by 1000 ppm NAA+2000 ppm IBA under Palampur conditions.

Elsheikh (2005) found in lime that, the cuttings treated with IBA @ 4000 ppm gave significantly the highest number of leaves (5.82), rooting percentage (80) and survival percentage (57) too.

Sharma *et al.* (2005) compared the effects of auxins on the rooting of mature stem cuttings of *Grewia optiva* and reported that the maximum root length of 3.18 cm and the highest rooting percentage of 93.33 were in the cuttings treated with 1000 @ ppm IBA compared to other cuttings treated with NAA.

Ganta (2004) reported that in fig, significantly the maximum length of shoot (17.07 cm), number of leaves per cutting (8.66) and survival percentage (73.40) were in the cuttings treated with IBA @ 4500 ppm + NAA @ 4500 ppm.

Noor *et al.* (2004) reported that in guava the soft wood cuttings treated with NAA @ 1000 ppm recorded early sprouting in 18 days while the maximum root number of 59.66 in cuttings treated with IBA @ 3000 ppm followed by the cuttings treated with NAA 3000 ppm which recorded a root number of 40.66 in guava.

The study conducted on the propagation of Negundo chastetree (*Vitex negundo* L.) by Tewary*et al.* (2004) clarified that the stem cuttings treated with stick (NAA with sodium as active ingredient) @ 1500 ppm gave the maximum average leaf number of 69 followed by the cuttings treated with 1500 ppm IBA which produced 57 leaves. And the maximum rooting percentage of 100 and the highest root length of 30.5 cm were also recorded in the cuttings treated with stick @ 500-1500 ppm followed by IAA @1500 ppm which had 80 percentage of rooting.

Antunes *et al.* (2003) carried outan experiment on the factors affecting the rooting of fig (*Ficus carica* L.) cutting at the University of Lavras, Brazil. They showed that IBA @ 100 ppm resulted in the maximum rooting percentage (75.5).

Borah and Das (2000) studied the efficacy of indole butyric acid (IBA) on the rooting of stem cuttings of some minor fruits of Assam. They observed that significantly maximum rooting percentage (41.45) and survival percentage (43.75) were observed with 3000 ppm IBA in summer.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Germplasm Center at Horticulture Farm in Sher-e-Bangla Agricultural University to study the rooting from different portions of stem the cuttings of croton plants using different plant growth regulators. Materials used and methodologies followed in the present investigation have been described in this chapter under different headings.

3.1 Experimental period

The experiment was conducted in both Kharif (March-September) and Rabi (October-February) seasons during the period from March-2019 to February-2020.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted at the Horticulture Germplasm Center, Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the study was situated in 23 0 74 / N latitude and 90 0 35 / E longitude.The altitude of the location was 8 m from the sea level (The Meteorological Department of Bangladesh, Agargaon, Dhaka).In Appendix I Map of Bangladesh's AEZ, the experimental site has been highlighted for easier understanding.

3.2.2 Climate and weather

The experimental site's climate was subtropical, with the winter season lasting from November to February, the pre-monsoon period, also known as the hot season, lasting from March to April, and the monsoon season lasting from May to October (Farukh*et al*., 2019). Appendix-II contains meteorological information about the temperature, relative humidity, and rainfall during the experiment period that was gathered from the Bangladesh Meteorological Department's Climate Division in Sher-e-Bangla Nagar, Dhaka.

3.2.3 Soil

The soil of the experimental area belongs to the Madhupur Tract. The analytical data of the soil sample collected from the experimental area were determined in Soil Resources Development Institute, Farmgate Dhaka Appendix II. The experimental site was a medium high land and pH of the soil was 5.6. The morphological characters of soil of the experimental plots are given below – AEZ No. 28. Soil series, Tejgaon. General soil, Non-calcarious dark grey.

3.3 Experimental materials

Three types cuttings viz., basal, middle and top cuttings of croton were used. The root promoting chemical i.e. Indole Butyric acid (IBA) and 1-Naphthaleneacetic acid (NAA) were used at different concentrations. The study was conducted with one variety of Croton (*Codiaeum variegatum*).

3.4 Experimental treatment

This experiment was carried out in both Kharif and Rabi seasons, with two factors, namely the portion of stem cutting which were similar in length and plant growth regulators, as mentioned below:

Factor A: Different portion of stem cuttings denoted as C:

C_1=Basal portion of the stem (15 cm)

C_2=Middle portion of the stem (15 cm)

C_3=Top portionof the stem (15 cm)

Factor B: Plant growth regulators denoted as S:

S_0=Control

S_1=IBA (Indole-3-butyric acid) @ 500 ppm

S_2= NAA (1-Naphthaleneacetic acid)@ 1000 ppm

3.5 Experimental design

The experiment had two factors, three replications, and arranged in the Randomized Complete Block design (RCBD). The experiment employed a total of 27unit plots with 9 treatments.

3.6 Detail of experimental preparation

3.6.1 Preparation of cuttings

The mature shoots of croton of the past season's growth were collected from Germplasm Center at Horticulture Farm in Sher-e-Bangla Agricultural University, Dhaka. The shoot was divided into three parts *i.e.* top, middle and basal stem cuttings having length of 15 cm with 8 nodes per cutting. The basal portion of mature stem was used as basal cutting. Similarly, the terminal and the middle portions of the stem was used as the top and the middle cuttings, respectively.

3.6.2 Land preparation

The land for the experiment was spaded several times and big and small clods were broken to obtain a good tilth. The weeds and stubbles were removed from the land. The land was then divided into 27 plots. The plots were raised to about 6 cm high from the soil surface. No chemical fertilizers were used in the soil.

3.6.3 Nursery bed preparation

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

3.6.4 Preparation of IBA solution

The required concentration of IBA (500 ppm) was prepared by dissolving its50 mg in a small quantity of NAOH and the volume was made up to 100 ml by adding distilled water, respectively.

3.6.5 Preparation of NAA solution

The required concentration of NAA(1000 ppm) was prepared by dissolving its 100 mg in a small quantity of NAOH and the volume was made up to 100 ml by adding distilled water.

3.6.6 Planting of cutting

Cuttings of ornamental shrub (Croton) were planted in the beds at a spacing of 15cm × 15cm. Two thirds of the length of the cuttings was inserted into the soil at an angle of 45°. Top portion of each cutting was covered with wax droplets for moisture conservation. Immediately after inserting watering was done uniformly by water can. Shading was provided by bamboo made overhead chatai at a height of 2 m to protect the cuttings from excessive rainfall and sunlight. The shading was kept for 4 weeks.

3.7 After care

3.7.1 Watering

Watering was done by using a water cane and maintained the proper moisture level. The beds were watered as and when required.

3.7.2 Plant protection

In order to prevent the infection of insects, pests and diseases, the plant protection schedule was followed during the investigation.

3.8 Experimental observations

The cuttings were kept under observation for 60 days. After that 3 cuttings were collected randomly from each of the 3 plots for data collection. Cuttings were uprooted from each plot by digging soils without tearing the roots. Base of each cutting was washed carefully in a bucket of clear water without damaging the roots. Then data were collected for the following parameters-

i. Sprouting percentage of cutting
ii. Days to shoot initiation (Days)
iii. Number of shoots per cutting
iv. Shooting %
v. Length of shoot (cm)
vi. Number of leaves per cutting
vii. Number of branches per cutting
viii. Number of roots per cutting

ix. Rooting %

x. Length of root (cm)

i. Sprouting percentage of cutting

The number of successfully rooted cuttings was recorded. Then the sprouting percentage of the cuttings of individual treatment was calculated by using the following formula

$$\text{Sprouting (\%)} = \frac{\text{Number of successfully sprouting cutting}}{\text{Total number of cuttings prepared}} \times 100$$

ii. Days to shoot initiation

The planted cuttings were observed daily and the number of days required for shoot initiation was recorded and their mean was used to calculate the days taken for the first shoot initiation to appear.

iii. Number of shoots per cutting

For the ensuing of shootings, newly emerged shoots were taken into consideration. Three cuts' worth of shoots were totaled up. The total number of shoots was then divided by 3 to determine the number of shoots per cutting. The number of shoots per cutting was recorded at the 60 days after planting.

iv. Shooting %

Shooting percentage is the ratio of the number of shoots present per cutting to the total number of shoots present in individual treatment.

$$\text{Shooting (\%)} = \frac{\text{Number of shoot present per cutting}}{\text{Total number of shoots present in the individual treatment}} \times 100$$

v. Length of shoot (cm)

The lengths of the three tagged cutting were measured from the base of sprouting of the shoot to the tip of the shoot and the average length was recorded at the 60 days after planting.

vi. Number of leaves per cutting

Total number of leaves per cutting was counted from three tagged cuttings and the mean was calculated and expressed as the number of leaves per cutting. That observation was recorded at the 60 days after planting.

vii. Number of branches per cutting

The number of branches present on each cutting was recorded and the mean was calculated. That observation was recorded at the 60 days after planting.

viii. Number of roots per cutting

To determine the average number of roots per rooted cutting, the total numbers of roots were divided by three cuttings. The number of roots per cutting was recorded at the 60 days after planting.

ix. Rooting %

Rooting percentage is the ratio of number of cuttings rooted to the total number of cuttings set in the plot. The response of rooting percentage by various growth regulators with different levels were calculated by using following formula at the 60 days after planting.

$$\text{Rooting (\%)} = \frac{\text{Number of cuttings rooted}}{\text{Total number of cuttings set for sprouting}} \times 100$$

x. Length of root (cm)

The length of the longest root per cutting in each treatment was measured with a scale and their mean was calculated and expressed in centimeters on 60th day after planting.

3.9 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

Two experiments were carried out in both Kharif and Rabi seasosns to investigate the rooting from different portion of stem cutting of croton (*Codiaeum variegatum*) using different plant growth regulators. The findings had been discussed, and possible interpretations were provided under the following headings.

4.1 Days required for shoot initiation

In both Kharif and Rabi seasons, the number of days required for croton shoot initiation was significantly influenced by the portion of the stem cutting (Figure 1).The highest days required for shoot initiation (21.11 and 23.78) were found in C_3 portion of the stem cutting in both Kharif and Rabi seasons. Oppositely, the lowest days required for shoot initiation (11.67 and 16.56) were found in the C_1 cutting position.

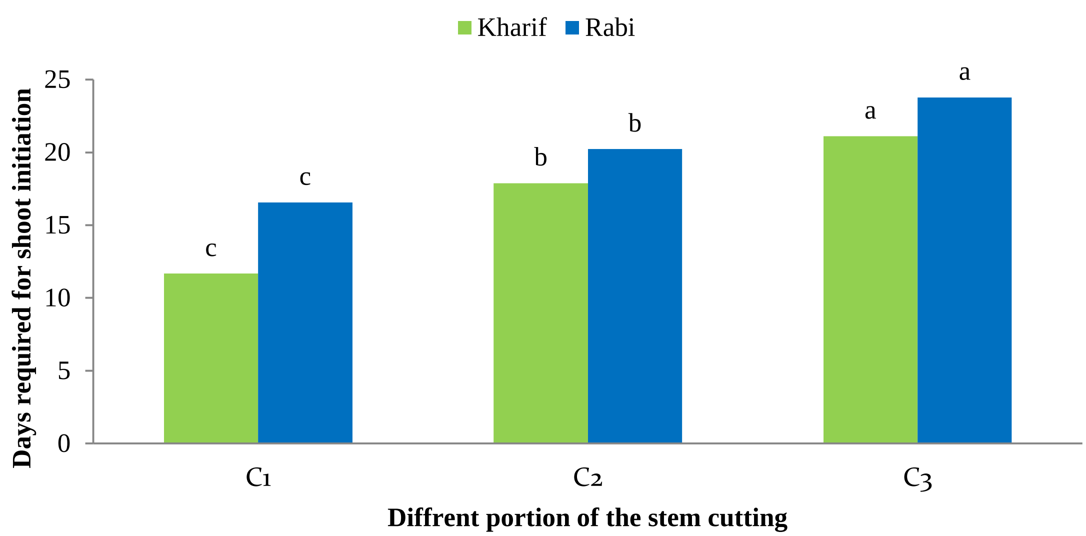

Figure 1. Effect of portion of the stem cutting on the days required for the shoot initiation of croton in both Kharif and Rabi seasons ($LSD_{(0.05)}$= 1.12 and 1.01 in both Kharifand Rabi seasons, respectively) In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, C_1=Basal portion, C_2=Middle portion and C_3=Top portion

During Kharif and Rabi seasons, the use of various plant growth regulators had a significant effect on the number of days required for croton shoot initiation (Figure 2). According to the present experimental results, the S_0 treatment had the highest days required for shoot initiation (18.44 and 21.67) during Kharif and Rabi seasons. During the Kharif and Rabi seasons, the S_1 treatment had the lowest days required for the shoot initiation (15.44 and 18.78).

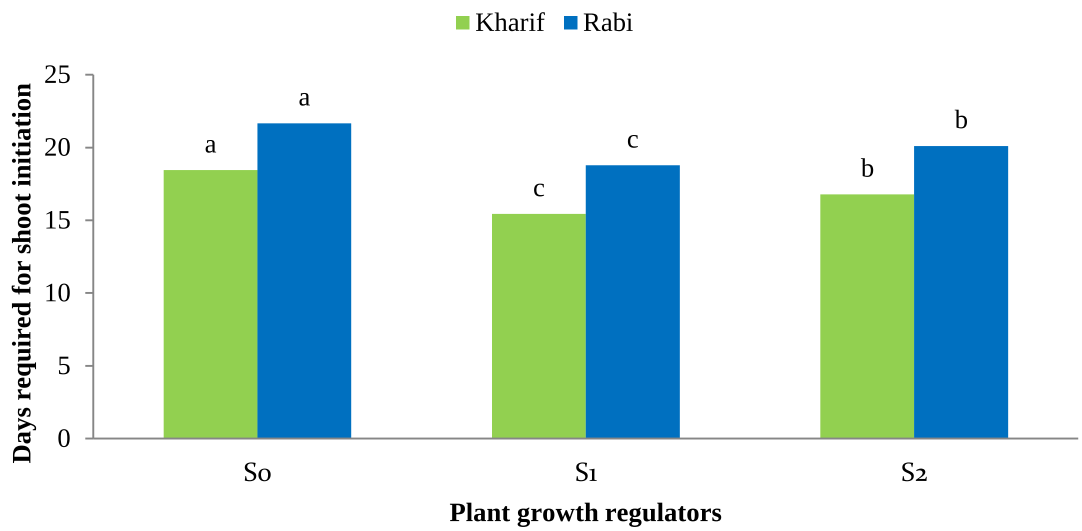

Figure 2. Effect of plant growth regulators on the days required for shoot initiation of croton in both Kharif and Rabi season ($LSD_{(0.05)}$= 1.00 and 1.00in both Kharif and Rabi seasons, respectively) In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, S_0=Control, S_1=IBA (Indole-3-butyric acid) @500 ppm and S_2= NAA (1-Naphthaleneacetic acid) @1000 ppm

The combined effect of the portion of stem cutting and the plant growth regulators significantly influenced the days required for croton shoot initiation in both Kharif and Rabi seasons (Table 1). The highest number of days required for shoot initiation (23.00 and 25.67) was found in the C_3S_0 treatment combination in both Kharif and Rabi seasons. In contrast, the C_1S_1 treatment combination had the lowest days required for the shoot initiation (10.00 and 15.33) in both Kharif and Rabi seasons which was statistically similar with C_1S_2 (16.67) treatment combination in Rabi season.

Table 1. Combined effect of the portion of stem cuttings and plant growth regulators on the number of days required for croton shoot initiation during both Kharif and Rabi seasons

Treatment combinations	Days to shoot initiation in	
	Kharif	Rabi
C_1S_0	13.00 d	17.67 fg
C_1S_1	10.00 e	15.33 h
C_1S_2	12.00 d	16.67 gh
C_2S_0	19.33 b	21.67 cd
C_2S_1	17.00 c	19.00 ef
C_2S_2	17.33 c	20.00 de
C_3S_0	23.00 a	25.67 a
C_3S_1	19.33 b	22.00 bc
C_3S_2	21.00 b	23.67 b
$LSD_{(0.05)}$	**1.95**	**1.75**
CV(%)	**6.69**	**5.02**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, C_1=Basal portion, C_2=Middle portionandC_3=Top portion, S_0=Control, S_1=IBA (indole-3-butyric acid)@500 ppm and S_2= NAA (1-naphthaleneacetic acid)@ 1000 ppm

4.1 Sprouting % of cutting

Different portions of stem cuttings significantly influenced the sprouting % of croton in both Kharif and Rabi seasons (Figure 3). The experimental result showed that C_1 (Basal portion) portion of stem cutting had the highest sprouting percentage (98.22 and 95.78 %) in both Kharif and Rabi seasons. However the lowest sprouting percentage (65.66 and 56.66 %) in both Kharif and Rabi season was found in C_3 (Top portion) portion of stem cutting. Patel and Patel (2018) reported maximum sprouting were observed in hardwood cuttings.

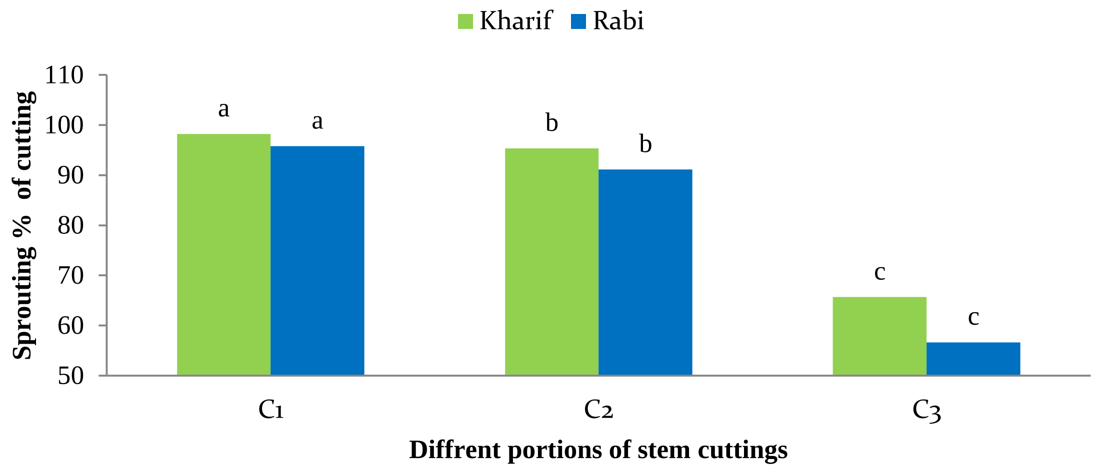

Figure 3. Effect of the portion of stem cuttings on sprouting % of croton in both Kharif and Rabi season (LSD$_{(0.05)}$= 1.12 and 2.11 both in Kharif and Rabi season) In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, C_1=Basal portion, C_2=Middle portion andC_3=Top portion

In both Kharif and Rabi seasons, different plant growth regulators had a significant effect on the sprouting percentage of croton (Figure 4).The experimental results showed that the application of S_1 (IBA (Indole-3-butyric acid) had the highest sprouting percentage (90.22 and 85.78) both in Kharif and Rabi season. Oppositely the lowest sprouting percentage (83.66) in Kharif season was found in S_0 (Control) treatment and in Rabi season the lowest sprouting percentage (77.77) was found in S_2 (NAA, 1-Naphthaleneacetic acid) treatment. Similar result was also observed by Devana (2018) who found that significantly minimum days were taken to start sprouting (7.17), as was recorded under the treatment of IBA @ 2000 ppm.

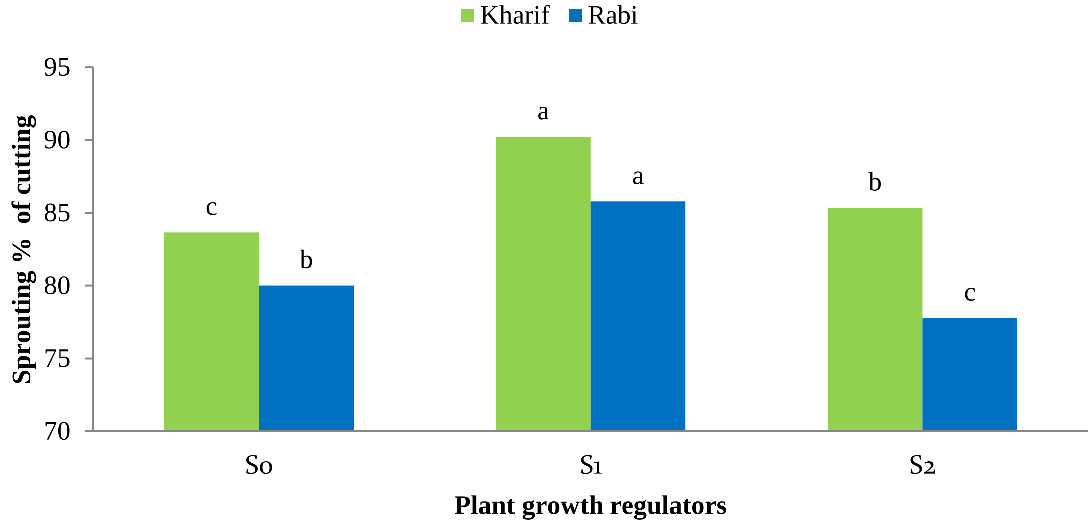

Figure 4. Effect of plant growth regulators on sprouting % of croton in both Kharif and Rabi seasons(LSD$_{(0.05)}$= 1.00 and 2.00 both in Kharif and Rabi seasons, respectively) In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, S_0=Control, S_1=IBA (indole-3-butyric acid) @500 ppm and S_2= NAA (1-naphthaleneacetic acid)@ 1000 ppm

The combined effect of the portion of stem cutting and plant growth regulators significantly influenced sprouting %of croton in both Kharifand Rabi seasons (Table 2). The present experimental result revealed that the highest sprouting percentages (100.00 and 97.33 %) in both Kharif and Rabi seasons were found in C_1S_1 treatment combination and were statistically similar with C_1S_0 (96.67 %) treatment combination in Rabi season. On the other hand, the lowest sprouting percentages (60.33 and 53.33 %) in both Kharif and Rabi season was found in C_3S_0 treatment combination which was statistically similar with C_3S_2 (53.33 %) treatment combination in Rabi season only.

Table 2. Combined effect of the portion of the stem cuttings and the plant growth regulators on the sprouting % of croton during Kharif and Rabi seasons

Treatment combinations	Sprouting percentage of cuttings in	
	Kharif	Rabi
C_1S_0	97.33 b	96.67 ab
C_1S_1	100.00 a	97.33 a
C_1S_2	97.33 b	93.33 bc
C_2S_0	93.33 d	90.00 cd
C_2S_1	97.33 b	96.67 ab
C_2S_2	95.33 c	86.67 d
C_3S_0	60.33 g	53.33 f
C_3S_1	73.33 e	63.33 e
C_3S_2	63.33 f	53.33 f
$LSD_{(0.05)}$	**1.95**	**3.67**
CV(%)	**1.31**	**2.61**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, C_1=Basal portion, C_2=Middle portion, C_3=Top portion, S_0=Control, S_1=IBA (Indole-3-butyric acid) 500 ppm and S_2= NAA (1-Naphthaleneacetic acid) 1000 ppm

4.3 Number of shoots per cutting

In both Kharif and Rabi seasons, the number of shoots per cutting of croton was significantly influenced by the portion of the stem cutting (Table 3). During Kharif and Rabi seasons at 60 DAP. the C1 portion of stem cutting recorded the highest number of shoots per cutting (2.71 and 2.38). But during Kharif and Rabi seasons, the C3 portion of stem cutting had the lowest numbers of shoots per cutting (2.16 and 1.55).

4.4 Number of roots per cutting

The number of roots per cutting of croton was significantly influenced by the portion of the stem cutting in both Kharif and Rabi seasons at the 60 DAP (Table 3). In Kharif and Rabi seasons, the C_1portion of stem cutting had the highest numbers of roots per cutting (8.44 and 4.47). But the C_3portion of the stem cutting had the lowest number of roots per cutting (4.18 and 2.07) during Kharif and Rabi seasons. Reddy (1984) argued that the basal cuttings gave more number of roots 25.55 than the terminal cuttings.

Table 3. Effect of portion of stem cuttings on the number of roots and shoots per cuttings of croton during both Kharif and Rabi seasons at 60 DAP

Treatments	Number of shoots per cutting in		Number of roots per cutting in	
	Kharif	**Rabi**	**Kharif**	**Rabi**
C_1	2.71 a	2.38 a	8.44 a	4.47 a
C_2	2.56 b	2.09 b	6.84 b	2.95 b
C_3	2.16 c	1.55 c	4.18 c	2.07 c
$LSD_{(0.05)}$	0.13	0.10	0.48	0.10
CV(%)	**5.35**	**4.99**	**7.49**	**3.87**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, C_1=Basal portion, C_2=Middle portion andC_3=Top portion

The use of plant growth regulators had a significant effect on the number of roots per cutting of croton during both Kharif and Rabi seasons at the 60 DAP (Table 4). According to the experimental results, during Kharif and Rabi seasons, the S_1treatment produced the highest numbers of roots per cutting of croton (7.40 and 3.91). Oppositely during both Kharif and Rabi seasons, the S_0 treatment had the lowest number of roots per cutting of croton (5.16 and 2.62). Similar result also observed by Jadhav (2007) who reported that the stem cuttings treated with 200 ppm IBA gave maximum number of root (41.67) in phalsa.

During Kharif and Rabi seasons, the use of various plant growth regulators had a significant effect on the number of shoots per croton cutting (Table 4). According to the experimental results, during both Kharif and Rabi seasons, the S_1treatment produced the highest numbers of shoots per cutting of croton (2.82 and 2.27). Oppositely during Kharif and Rabi seasons, the S_0 treatment had the lowest numbers of shoots per cutting of croton (2.11 and 1.75).

Table 4. Effect of plant growth regulators on the number of shoots and roots per cutting of croton during Kharif and Rabi seasons at 60 DAP

Treatments	Number of shoots per cutting		Number of roots per cutting	
	Kharif	Rabi	Kharif	Rabi
S_0	2.11 c	1.75 c	5.16 c	2.62 c
S_1	2.82 a	2.27 a	7.40 a	3.91 a
S_2	2.49 b	2.00 b	6.90 b	2.95 b
$LSD_{(0.05)}$	0.10	0.08	0.40	0.12
CV(%)	**5.35**	**4.99**	**7.49**	**3.87**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_0=Control, S_1=IBA (Indole-3-butyric acid)@ 500 ppm and S_2= NAA (1-Naphthaleneacetic acid)@ 1000 ppm

The combined effect of the portion of the stem cutting and the plant growth regulators significantly influenced the number of shoots per cutting of croton in both Kharif and Rabi seasons at 60 DAP (Table 5). The experimental result revealed that in both Kharif and Rabi seasons, the C_1S_1 treatment combination recorded the highest number ofshoots per cutting of croton (2.93 and 2.60) which were statistically similar with C_2S_1 (2.87 and 2.47) treatment combination in both Kharif and Rabi seasons and with C_2S_2 (2.73) treatment combination in both Kharif and Rabi seasons. On the contraty, in both Kharif and Rabi seasons, the C_3S_0 treatment combination had the lowest numbers of shoots per croton cutting (1.87 and 1.40) which were statistically similar with C_3S_2 (1.93 and 1.53) treatment combination in both Kharif and Rabi and with C_3S_0(1.87) treatment combination in Kharif season only.

In both Kharif and Rabi seasons, the combined effect of portion of stem cutting and plant growth regulators significantly influenced the number of roots per cutting of croton (Table 5). Experimental result revealed that in both the Kharif and Rabi seasons, the C_1S_1 treatment combination recorded the highest number of roots per cutting of croton (9.33 and 5.80). While in both the Kharif and Rabi seasons, the C_3S_0 treatment combination had the lowest number of roots per croton cutting (1.93 and 1.27).

Table 5. Combined effect of portion of stem cutting and plant growth regulators on the number of roots and shoots per cutting of croton during Kharif and Rabi seasons

Treatment combinations	Number of roots per cutting		Number of shoots per cutting	
	Kharif	Rabi	Kharif	Rabi
C_1S_0	7.67 bc	3.67 c	2.40 c	2.13 c
C_1S_1	9.33 a	5.80 a	2.93 a	2.60 a
C_1S_2	8.33 b	3.93 b	2.80 ab	2.40 b
C_2S_0	5.87 d	2.93 e	2.07 d	1.73 d
C_2S_1	7.81 b	3.20 d	2.87 ab	2.47 ab
C_2S_2	6.83 c	2.73 e	2.73 ab	2.07 c
C_3S_0	1.93 e	1.27 g	1.87 d	1.40 e
C_3S_1	5.07 d	2.73 e	2.67 b	1.73 d
C_3S_2	5.53 d	2.20 f	1.93 d	1.53 e
$LSD_{(0.05)}$	**0.84**	**0.21**	**0.22**	**0.17**
CV(%)	**7.49**	**3.87**	**5.35**	**4.99**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, C_1=Basal portion, C_2=Middle portion, C_3=Top portion, S_0=Control, S_1=IBA (indole-3-butyric acid) @ 500 ppm and S_2= NAA (1-naphthaleneacetic acid)@1000 ppm

4.5 Shooting %

Croton shooting percentage was significantly influenced by the portion of stem cutting in both Kharif and Rabi seasons (Table 6). The C_1portion of the cutting had the highest shooting percentages during Kharif and Rabi seasons (27.10 and 23.77 %). While the C_3portion of the cutting had the lowest shooting percentages during Kharif and Rabi seasons (21.57 and 15.53 %).

4.6 Rooting %

The rooting percentage was significantly influenced by the portion of the stem cutting in both Kharif and Rabi seasons (Table 6). The C_1portion of the stem cutting had the highest rooting percentage during Kharif and Rabi seasons (84.43 and 44.67%). Oppositely the

C_3portion of the stem cutting had the lowest rooting percentages during Kharif and Rabi seasons (41.77 and 20.67 %). The result were similar with the findings of Malakar *et al.* (2019) who found that significantly the highest rooting percentage (24.44) was in the hardwood cutting .

Table 6. Effect of portion of stem cutting on shooting and rooting percentages of croton during Kharif and Rabi seasons at 60 DAP

Treatments	Shooting % of cutting in		Rooting % of cutting in	
	Kharif	Rabi	Kharif	Rabi
C_1	27.10 a	23.77 a	84.43 a	44.67 a
C_2	25.57 b	20.90 b	68.37 b	29.53 b
C_3	21.57 c	15.53 c	41.77 c	20.67 c
$LSD_{(0.05)}$	0.44	0.99	2.43	2.11
CV(%)	**2.78**	**4.98**	**3.76**	**6.71**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, C_1=Basal portion, C_2=Middle portion andC_3=Top portion

The use of various plant growth regulators had a significant effect on the shooting percentage of croton cuttings during both Kharif and Rabi seasons (Table 7). During Kharif and Rabi seasons, the S_1treatment produced the highest percentage of croton shooting (28.23 and 22.67 %). While the S_0 treatment had the lowest croton shooting percentage during Kharif and Rabi seasons (21.13 and 17.53 %).

The use of various plant growth regulators had a significant effect on the rooting percentage of croton cuttings during both Kharif and Rabi seasons (Table 7). During Kharif and Rabi seasons, the S_1treatment produced the highest percentage of croton rooting (74.03 and 39.10 %). While the S_0 treatment had the lowest croton rooting percentage during Kharif and Rabi seasons (51.57 and 26.23 %). The result obtained from the present study was similar with the findings of Kuntagol *et al.* (2018) who recorded that significantly maximum rooting percentage (36.22) was observed in IBA @3000 ppm. Sivaji *et al.* (2014) revealed that significantly highest rooting percentage (69.71) was observed in cuttings treated with IBA @ 3000 ppm.

Table 7. Effect of plant growth regulators on shooting and rooting percentages of croton during Kharif and Rabi seasons at 60 DAP

Treatments	Shooting % of cutting		Rooting % of cutting	
	Kharif	**Rabi**	**Kharif**	**Rabi**
S_0	21.13 c	17.53 c	51.57 c	26.23 c
S_1	28.23 a	22.67 a	74.03a	39.10 a
S_2	24.87 b	20.00 b	68.97b	29.53 b
$LSD_{(0.05)}$	0.40	0.80	2.40	2.00
CV(%)	**2.78**	**4.98**	**3.76**	**6.71**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_0=Control, S_1=IBA (indole-3-butyric acid)@ 500 ppm and S_2= NAA (1-naphthaleneacetic acid) @ 1000 ppm

In both Kharif and Rabi seasons, the combined effect of portion of stem cutting and plant growth regulators significantly influenced the shooting percentage of croton (Table 8). The experimental results showed that the C_1S_1 treatment combination had the highest croton shooting percentage in both Kharif and Rabi seasons (29.30 and 26.00). While the C_3S_0 treatment combination had the lowest croton shooting percentage in both the Kharif and Rabi seasons (18.70 and 14.00) which were statistically similar with the C_3S_2 (19.30 and 15.30) treatment combination in both Kharif and Rabi seasons.

Table 8. Combined effect of the portion of stem cutting and the plant growth regulators on the shooting and rooting percentages of croton during Kharif and Rabi seasons at 60 DAP

Treatment combinations	Shooting % of cutting in		Rooting % of cutting in	
	Kharif	Rabi	Kharif	Rabi
C_1S_0	24.00 e	21.30 c	76.70 c	36.70 b
C_1S_1	29.30 a	26.00 a	93.30 a	58.00 a
C_1S_2	28.00 bc	24.00 b	83.30 b	39.30 b
C_2S_0	20.70 f	17.30 d	58.70 e	29.30 cd
C_2S_1	28.70 ab	24.70 ab	78.10 c	32.00 c
C_2S_2	27.30 cd	20.70 c	68.30 d	27.30 d
C_3S_0	18.70 g	14.00 e	19.30 g	12.70 f
C_3S_1	26.70 d	17.30 d	50.70 f	27.30 d
C_3S_2	19.30 g	15.30 e	55.30 e	22.00 e
$LSD_{(0.05)}$	**0.76**	**1.73**	**4.22**	**3.67**
CV(%)	**2.78**	**4.98**	**3.76**	**6.71**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, C_1=Basal portion, C_2=Middle portion, C_3=Top portion, S_0=Control, S_1=IBA (Indole-3-butyric acid) @ 500 ppm and S_2= NAA (1-Naphthaleneacetic acid) @ 1000 ppm

4.7 Root length

The root length was significantly influenced by the portion of the stem cutting in both Kharif and Rabi seasons (Figure 5). During Kharif and Rabi seasons, the C_1portion of the cutting had the highest root length (5.03 and 2.73 cm) while the C_3 portion of the cutting had the shortest root length during Kharif and Rabi seasons (3.21 and 1.98 cm). Raveendran *et al.* (2010) reported that the root length was maximum fo the basal part, medium in the middle part and the lowest in the apical part in bamboo *Dendrocalamus giganteus.*

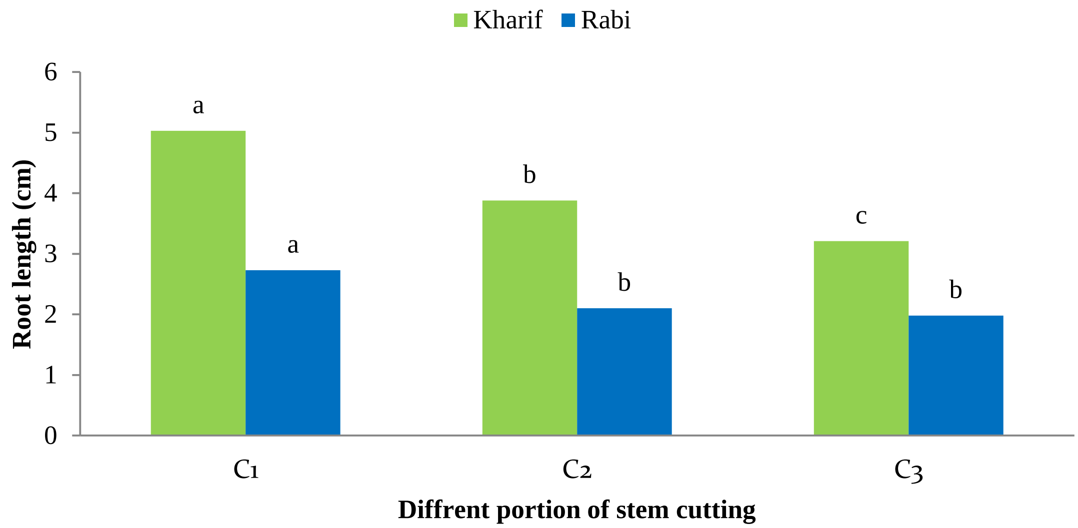

Figure 5. Effect of portion of stem cutting on the root length of croton in both Kharif and Rabi seasons(LSD$_{(0.05)}$= 0.12 and 0.13 in bothKharif and Rabi seasons) In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, C_1=Basal portion, C_2=Middle portion, C_3=Top portion

Various plant growth regulators had a significant effect on the root length of croton cuttings during Kharif and Rabi seasons (Figure 6). The S_1treatment produced the longest roots during both Kharif and Rabi seasons (4.93 and 2.67 cm) while the S_0 treatment had the shortest root lengths during Kharif and Rabi seasons (2.81 and 1.84 cm). Egbe *et al.* (2012) observed that the highest root lengths of 1.23 cm, 2.48 and 1.48 cm were in the leafy stem cuttings of albizia, blighia and lophira respectively, when treated with IBA @16000 µg/ml under shade house conditions.

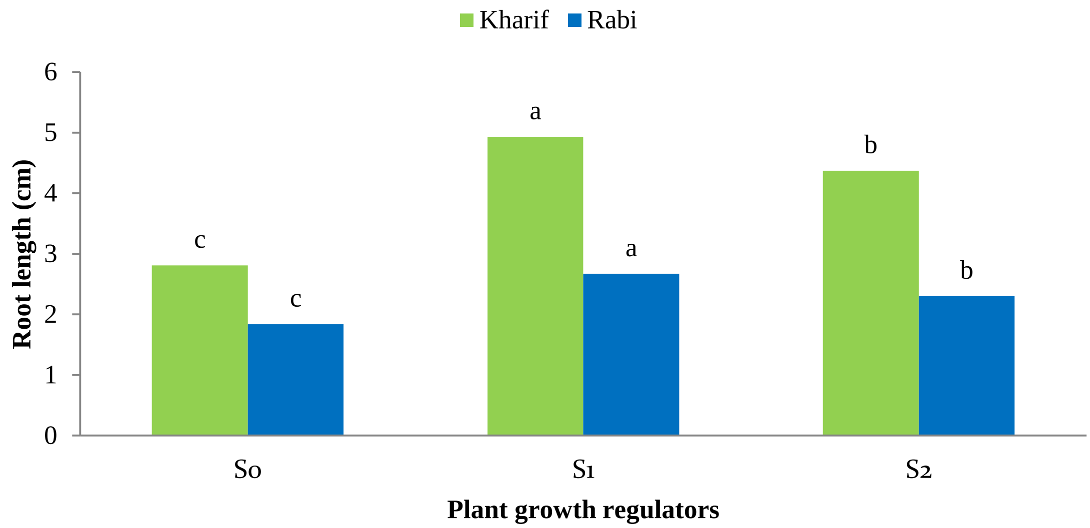

Figure 6. Effect of plant growth regulators on root length of croton in both Kharif and Rabi seasons ($LSD_{(0.05)}$= 0.13 and 0.10 in both Kharif and Rabi seasons)

In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, S_0=Control, S_1=IBA (Indole-3-butyric acid) @500 ppm and S_2= NAA (1-Naphthaleneacetic acid) @1000 ppm

The root length was significantly influenced by the combined effect of portion of stem cutting and plant growth regulators in both the Kharif and Rabi seasons (Table 9). According to the experimental results the C_1S_1 treatment combination had produced the longest roots in both Kharif and Rabi seasons (6.03 and 2.94 cm) while in both Kharif and Rabi seasons, the C_3S_0 treatment combination had the shortest croton root length (1.65 and 1.19 cm).

4.8 Shoot length

The portion of the stem cutting had a significant influence on the shoot length in both Kharif and Rabi seasons (Figure 7). The C_1portion of stem cutting had the longest shoots during Kharif and Rabi seasons (11.59 and 8.84 cm) while during Kharif and Rabi seasons, the C_3portion had the shortest shoots (7.45 and 4.14 cm). Patel and Patel (2018) reported that the maximum shoot length (5.01 and 8.36 cm) was observed in hardwood cutting.

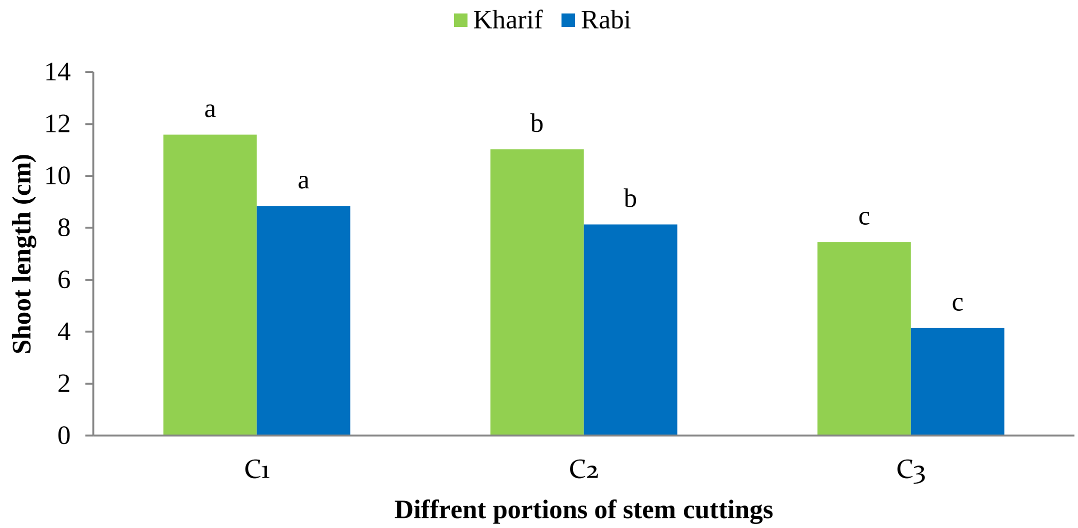

Figure 7. Effect of portions of stem cutting on shoot length of croton in both Kharif and Rabi seasons ($LSD_{(0.05)}$= 0.53 and 0.33 in both Kharif and Rabi seasons)
In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, C_1=Basal portion, C_2=Middle portion andC$_3$=Top portion

Various plant growth regulators had a significant effect on the shoot length of the cuttings during Kharif and Rabi seasons (Figure 8). During Kharif and Rabi seasons, the plant growth regulator S_1produced the highest shoot lengths (11.44 and 8.03 cm) while the S_0 treatment had the shortest shoots during Kharif and Rabi seasons (8.45 and 5.99 cm). Sivaji *et al.* (2014) revealed that significantly the highest shoot length (16.82 cm) was in cuttings treated with IBA @ 3000 ppm.

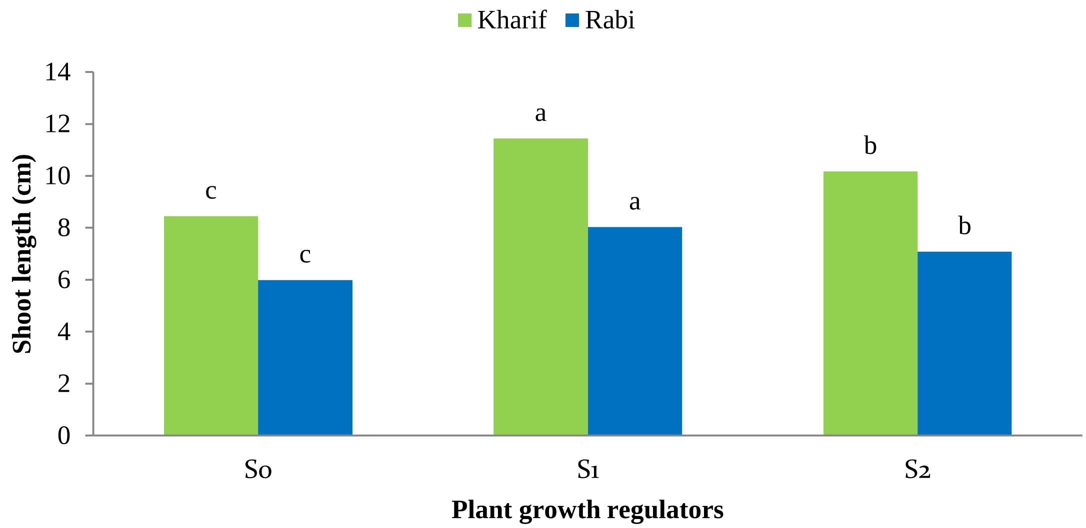

Figure 8. Effect of plant growth regulators on shoot length of croton in both Kharif and Rabi seasons ($LSD_{(0.05)}$= 0.50 and 0.30 in both Kharif and Rabi seasons) In the bar graph having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, S_0=Control, S_1=IBA (Indole-3-butyric acid) @500 ppm and S_2= NAA (1-Naphthaleneacetic acid) @1000 ppm

The shoot length was significantly influenced by the combined effect of the portion of the cutting and the plant growth regulators in both Kharif and Rabi seasons (Table 9). According to the experimental results, the C_1S_1 treatment combination had the longest shoot lengths in both Kharif and Rabi seasons (13.47 and 10.33 cm). Contrastly, in both Kharif and Rabi seasons, the C_3S_0 treatment combination had the shortest shoot lengths (6.35 and 3.45 cm).

Table 9. Combined effect of portion of stem cutting and plant growth regulators on the root and shoot lengths of croton during Kharif and Rabi seasons at 60 DAP

Treatment combinations	Root length(cm) in		Shoot length(cm) in	
	Kharif	Rabi	Kharif	Rabi
C_1S_0	4.40 c	2.59 bc	9.83 c	7.29 d
C_1S_1	6.03 a	2.94 a	13.47 a	10.33 a
C_1S_2	4.65 b	2.65 b	11.47 b	8.89 b
C_2S_0	2.38 e	1.73 f	9.17 c	7.23 d
C_2S_1	4.65 b	2.39 cd	12.71 a	9.03 b
C_2S_2	4.60 bc	2.17 de	11.17 b	8.13 c
C_3S_0	1.65 f	1.19 g	6.35 e	3.45 f
C_3S_1	4.10 d	2.69 b	8.13 d	4.73 e
C_3S_2	3.87 d	2.07 e	7.88 d	4.23 e
$LSD_{(0.05)}$	0.23	0.22	0.93	0.57
CV(%)	3.30	5.83	5.37	4.71

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, C_1=Basal portion, C_2=Middle portion, C_3=Top portion, S_0=Control, S_1=IBA (Indole-3-butyric acid) @ 500 ppm and S_2= NAA (1-Naphthaleneacetic acid) @ 1000 ppm

4.9Number of leaves per cutting

The portion of stem cutting had a significant influence on the leaf number in both Kharif and Rabi seasons (Table 10). The C_1 portion of the cutting had the highest leaves per cutting throughout Kharif and Rabi seasons (17.62 and 11.34). But during Kharif and Rabi seasons, the C_3 portion of the cutting had the lowest number of leaves per cutting (13.82 and 9.20). The findings were similar to those of Singh *et al.* (2018), who reported that the maximum number of leaves (7.44) were observed in hardwood cutting.

4.10 Number of branches per cutting

The portion of stem cutting had a significant influence on the branch number in both Kharif and Rabi seasons (Table 10). The C_1 portion of the cutting had the highest numbers of branches per cutting throughout Kharif and Rabi seasons (1.97 and 1.64) which were statistically similar with C_2 portion of the cutting (1.64) in Rabi season. But during Kharif and Rabi seasons, the C_3 portion of the cutting had the lowest leaves per cutting (1.88 and 1.55) which were statistically similar with C_2 portion of the cutting (1.91) in Kharif season.

Table 10. Effect of portion of stem cutting on the number of leaves per cutting and number of branches per cutting of croton during Kharif and Rabi seasons

Treatments	Number of leaves per cutting		Number of branches per cutting	
	Kharif	**Rabi**	**Kharif**	**Rabi**
C_1	17.62 a	11.34 a	1.97 a	1.64 a
C_2	16.13 b	10.18 b	1.91 b	1.64 a
C_3	13.82 c	9.20 c	1.88 b	1.55 b
$LSD_{(0.05)}$	0.40	0.31	0.04	0.07
CV(%)	**2.78**	**3.24**	**2.29**	**4.38**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, C_1=Basal portion, C_2=Middle portion andC_3=Top portion

During both Kharif and Rabi seasons, different plant growth regulators had a significant effect on the leaf number of cuttings (Table 11). The S_1 treatment produced the highest number of leaves per cutting during Kharif and Rabi seasons (18.38 and 12.07). But during Kharif and Rabi seasons, the S_0 treatment had the least numbers of leaves per cutting (13.84 and 8.80). Devana (2018) found significantly the maximum number of leaves per cutting (10.07) was recorded under the treatment of IBA @ 2000 ppm.

In both Kharif and Rabi seasons, the combined effect of the portion of the cutting and plant growth regulators significantly influenced the number of leaves per cutting (Table 12). Experimental result revealed that the C_1S_1 treatment combination had the highest numbers of leaves per cutting in both Kharif and Rabi seasons (20.60 and 13.27) while the C_3S_0 treatment combination had the lowest numbers of leaves per cutting in both Kharif and Rabi seasons (11.73 and 8.07).

During Kharif and Rabi seasons, different plant growth regulators had a significant effect on the branch number of cuttings (Table 11). The S_1 treatment produced the highest numbers of branches per cutting during Kharif and Rabi seasons (2.06 and 1.75) which were statistically similar with the S_2 portion of the cutting (1.69) in Rabi season. But, during Kharif and Rabi seasons, the S_0 treatment had the least numbers of branches per cutting (1.73 and 1.40).

Table 11. Effects of plant growth regulators on the number of leaves per cutting and number of branches per cutting of croton during Kharif and Rabi seasons

Treatments	Number of leaves per cutting in		Number of branches per cutting in	
	Kharif	**Rabi**	**Kharif**	**Rabi**
S_0	13.84 c	8.80 c	1.73 c	1.40 b
S_1	18.38 a	12.07 a	2.06 a	1.75 a
S_2	15.36 b	9.85 b	1.97 b	1.69 a
$LSD_{(0.05)}$	0.44	0.33	0.03	0.06
CV(%)	**2.78**	**3.24**	**2.29**	**4.38**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_0=Control, S_1=IBA (Indole-3-butyric acid) @ 500 ppm and S_2= NAA (1-Naphthaleneacetic acid) @ 1000 ppm

The combined effect of portion of stem cutting and plant growth regulators significantly influenced the number of branches per cutting in both Kharif and Rabi seasons (Table 12). The Present experimental result reveal that the C_1S_1 treatment combination produced the highest numbers of branches per cutting in both Kharif and Rabi seasons (2.13 and 1.80) which were statistically similar with C_1S_2 (2.06) and C_3S_1 (2.06) treatment combination in Kharif season and with C_1S_2 (1.73), C_2S_1 (1.73), C_2S_2 (1.73) and C_3S_1 (1.73) treatment combinations in Rabi season. Oppositely, the C_3S_0 treatment combination had the lowest numbers of branches per cutting in both Kharif and Rabi seasons (1.66 and 1.33) which were statistically similar with C_1S_0 (1.73 and 1.40) treatment combination in both Kharif and Rabi seasons.

In both Kharif and Rabi seasons, the combined effect of portion of stem cutting and plant growth regulators significantly influenced the number of leaves per cutting (Table 12). Experimental result revealed that the C_1S_1 treatment combination had the highest numbers of leaves per cutting of croton plant in both Kharif and Rabi seasons (20.60 and 13.27) while the C_3S_0 treatment combination had the lowest numbers of leaves per cutting in both Kharif and Rabi seasons (11.73 and 8.07).

Table 12. Combined effects of portion of stem cutting and plant growth regulators on the number of leaves per cutting and numbers of branches per cutting of croton during Kharif and Rabi seasons

Treatment combinations	Number of leaves per cutting		Number of branches per cutting	
	Kharif	Rabi	Kharif	Rabi
C_1S_0	15.47 d	9.67 d	1.73 de	1.40 cd
C_1S_1	20.60 a	13.27 a	2.13 a	1.80 a
C_1S_2	16.80 c	11.07 c	2.06 ab	1.73 a
C_2S_0	14.33 e	8.67 e	1.80 d	1.47 c
C_2S_1	18.60 b	12.07 b	2.00 bc	1.73 a
C_2S_2	15.47 d	9.80 d	1.93 c	1.73 a
C_3S_0	11.73 f	8.07 f	1.66 e	1.33 d
C_3S_1	15.93 d	10.87 c	2.06 ab	1.73 a
C_3S_2	13.80 e	8.67 e	1.93 c	1.60 b
$LSD_{(0.05)}$	**0.76**	**0.57**	**0.07**	**0.12**
CV(%)	**2.78**	**3.24**	**2.29**	**4.38**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, C_1=Basal portion, C_2=Middle portion and C_3=Top portion, S_0=Control, S_1=IBA (indole-3-butyric acid) @500 ppm and S_2= NAA (1-naphthaleneacetic acid) @ 1000 ppm

CHAPTER V

SUMMARY AND CONCLUSIONS

Two experiments were conducted at Horticulture Farm in Sher-e-Bangla Agricultural University, Dhaka during the period from March-2019 to February-2020 to study the rooting from different portion of stem cutting of croton (*Codiaeum variegatum*) using different plant growth regulators. The experiment consisted of two factors, and followed Randomized Complete Block design (RCBD) with three replications. Factor A. Portion of stem cutting denoted as C:C_1=Basal portion of the stem, C_2=Middle portion of the stem, C_3=Top portion of the stem, and Factor B: Plant growth regulators denoted as S:S_0=Control, S_1=IBA (indole-3-butyric acid) @500 ppm and S_2= NAA (1-naphthaleneacetic acid)@1000 ppm. For the purpose of evaluating the experimental outcomes, data on various parameters were evaluated.

The experimental results revealed that, the C_1 (Basal portion) portion of the cutting had the highest sprouting percentages (98.22 and 95.78), lowest days required for shoot initiation (11.67 and 16.56),highest numbers of roots per cutting (8.44 and 4.47), shoots per cutting (2.71 and 2.38), rooting percentages (84.43 and 44.67), shooting percentages (27.10 and 23.77), root length (5.03 and 2.73 cm), shoot lengths (11.59 and 8.84 cm), leaves per cutting (17.62 and 11.34) and numbers of branches per cutting (1.97 and 1.64) throughout Kharif and Rabi seasons. But the lowest sprouting percentages (65.66 and 56.66), highest days required for shoot initiation (21.11 and 23.78),lowest number of roots per cutting (4.18 and 2.07), shoots per cutting (2.16 and 1.55), rooting percentage (41.77 and 20.67),shooting percentages (21.57 and 15.53),root lengths (3.21 and 1.98 cm), shoot lengths (7.45 and 4.14 cm), leaves per cutting (13.82 and 9.20) and the lowest leaves per cutting (1.88 and 1.55) were found in the C_3 portion of the cutting in both Kharif and Rabi seasons.

In the case of the applications of different plant growth regulators, the S_1treatment (IBA (Indole-3-butyric acid @ 500 ppm) had the highest sprouting percentages (90.22 and 85.78), the lowest days required for shoot initiation (15.44 and 18.78), the highest numbers of roots per cutting (7.40 and 3.91), shoots per cutting (2.82 and 2.27), rooting (74.03 and 39.10 %), shooting (28.23 and 22.67 %), root lengths (4.93 and 2.67 cm), shoot lengths (11.44 and 8.03 cm), leaves per cutting (18.38 and 12.07) and branches per cutting (12.06 and 1.75) during Kharif and Rabi seasons. But the lowest sprouting percentage (83.66) in Kharif season was found in the S_0 (Control) treatment and in Rabi season the lowest sprouting percentage (77.77) was found in the S_2 (NAA, 1-naphthaleneacetic acid) treatment. The S_0(Control) treatment required the highest days for the shoot initiation (18.44 and 21.67). This treatment (S_0) also had the lowest roots per cutting (5.16 and 2.62), shoots per cutting (2.82 and 2.27), rooting percentages (51.57 and 26.23), shooting percentages (21.13 and 17.53), root lengths (2.81 and 1.84 cm),shoot lengths (8.45 and 5.99 cm), leaves per cutting (13.84 and 8.80) and branches per cutting (1.73 and 1.40) during Kharif and Rabi seasons.

In the case of the combined effects, the highest sprouting percentages (100.00 and 97.33), lowest days required for shoot initiation (10.00 and 15.33), roots per cutting (9.33 and 5.80), shoots per cutting (2.93 and 2.60), rooting percentages (93.30 and 58.00), shooting percentages (29.30 and 26.00), root lengths (6.03 and 2.94 cm), shoot lengths (13.47 and 10.33 cm), leaves per cutting (20.60 and 13.27) and branches per cutting (2.13 and 1.80) in both Kharif and Rabi season were found in the C_1S_1 treatment combination. However, the C_3S_0 treatment combination had the lowest sprouting percentages (60.33 and 53.33), highest days required shoot initiation (23.00 and 25.67), the lowest numbers of roots per cutting (1.93 and 1.27), shoots per croton cutting (1.87 and 1.40),rooting percentages (19.30 and 12.70), shooting percentages (18.70 and 14.00), root lengths (1.65 and 1.19 cm), shoot lengths (6.35 and 3.45 cm), leaves per cutting (20.60 and 13.27) and branches per cutting (1.66 and 1.33) in both Kharif and Rabi seasons.

Conclusion

The present experimental results revealed that the different portion of stem cutting and the applications of plant growth regulators significantly influenced the root formation of croton (*Codiaeum variegatum*) during both Kharif and Rabi seasons.

So, the results of the present work paved the path to conclude that:

i. Basal cutting was better comparable to others cutting positions

ii. Use of IBA @ 500 ppm as growth regulators performed superior

iii. Kharif season was favorable and

iv. C_1S_1 was the best treatment combination recording the maximum value of various attributes related to the growth of shoot and root parameters of croton cuttings.

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APPENDICES

Appendix I. A map showing the experimental location under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	**Characteristics**
AEZ	AEZ-28, Madhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Horticulture Research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0- 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29
Sand	26
Silt	45
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III. Monthly meteorological information during the period from March 2019 to February, 2020

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2019	March	32.9	20.1	61	54
	April	34.1	23.6	67	138
	May	33.4	24.7	76	269
	June	34	27.3	76	134
	July	32.6	26.8	81	114
	August	32.6	25.5	80	106
	September	32.4	25.7	80	86
	October	31.2	23.9	76	52
	November	29.6	19.8	53	00
	December	28.8	19.1	47	00
2020	January	25.5	13.1	41	00
	February	25.9	14.0	34	7.7

Source:Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Analysis of variance of the data of number of sprouting percentage of croton during Kharif and Rabi season

Source	**DF**	Mean square of sprouting percentage at	
		Kharif	Rabi
Replication (R)	2	2.78	9.00
Cutting (C)	2	2922.60*	4107.60*
Hormone (H)	2	104.52*	153.47*
C×H	4	26.80*	19.06*
Error	16	1.28	4.50

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data of number of days required for croton shoot initiation during Kharif and Rabi seasons

Source	**DF**	Mean square ofdays to shoot initiation	
		Kharif	Rabi
Replication (R)	2	2.778	1.778
Cutting (C)	2	207.382*	117.406*
Hormone (H)	2	20.333*	18.872*
C×H	4	0.782*	0.426*
Error	16	1.278	1.028

Ns: Non significant
*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data number of roots and shoots per cutting of croton during Kharif and Rabi seasons

Source	**DF**	Mean square of number of roots per cutting		Mean square of number of roots per cutting	
		Kharif	Rabi	Kharif	Rabi
Replication (R)	2	0.1111	0.0900	0.02054	0.02054
Cutting (C)	2	41.7921*	13.2545*	0.73453*	1.57210*
Hormone (H)	2	12.4977*	4.0194*	1.13523*	0.59320*
C×H	4	1.9681*	0.9184*	0.11843*	0.03410*
Error	16	0.2361	0.0150	0.01754	0.01004

Ns: Non significant
*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of rooting and shooting percentage of croton during Kharif and Rabi seasons

Source	**DF**	Mean square of rooting percentage		Mean square of shooting percentage	
		Kharif	Rabi	Kharif	Rabi
Replication (R)	2	13.44	9.00	0.444	1.000
Cutting (C)	2	4179.21*	1325.45*	73.453*	157.210*
Hormone (H)	2	1249.77*	401.94*	113.523*	59.320*
C×H	4	196.81*	91.84*	11.843*	3.410*
Error	16	5.94	4.50	0.194	1.000

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of root and shoot length of croton during Kharif and Rabi seasons

Source	**DF**	Mean square of root length		Mean square of shoot length	
		Kharif	Rabi	Kharif	Rabi
Replication (R)	2	0.0278	0.04000	0.6400	0.1600
Cutting (C)	2	7.6257*	1.44343*	45.2071*	57.8041*
Hormone (H)	2	10.8457*	1.58023*	20.2291*	9.3797*
C×H	4	1.0000*	0.28403*	0.9890*	0.6181*
Error	16	0.0178	0.01750	0.2900	0.1100

Ns: Non significant

*: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of number of leaves per cutting and number of branches per cutting of croton during Kharif and Rabi seasons

Source	**DF**	Mean square of number of leaves per cutting		Mean square of number of branches per cutting	
		Kharif	Rabi	Kharif	Rabi
Replication (R)	2	0.4444	0.1600	0.00444	0.01000
Cutting (C)	2	33.0554*	10.2643*	0.01923*	0.02430*
Hormone (H)	2	47.9425*	25.0543*	0.26763*	0.31720*
C×H	4	0.6080*	0.1703*	0.01253*	0.00610*
Error	16	0.1944	0.1100	0.00194	0.00500

Ns: Non significant

*: Significant at 0.05 level of probability