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Effect of growth regulators on sprouting and rooting of bougainvillea hardwood cuttings

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Abstract
An experiment entitled "Effect of growth regulators on sprouting and rooting of Bougainvillea hardwood cuttings" were carried out during the year 2020 - 21 at ornamental plants nursery, Department of Floriculture and Landscape Architecture, Dr. PDKV, Akola. The experiment was laid out in completely randomized design with thirteen treatments which were replicated three times.
The results of the present investigation indicates that, among the different concentrations of IBA and NAA the hardwood cuttings treated with IBA 2000 ppm resulted better in comparison with control, with respect to different root, shoot and growth parameters *i.e*. days to sprouting (9.63), number of leaves (84.5), number of shoots (3.92), fresh and dry weight of shoot (11.07 and 0.94 g respectively), plant height (84.66 cm), days to rooting (15.6), number of roots per cutting (26.5), length of main root (18.75 cm), survival percentage of rooted cuttings (95.33%), root volume (1.95 ml), fresh and dry weight of roots per cuttings (1.54 and 0.40 g respectively), stem girth (1.13 cm), plant spread (81.57 cm), mortality percentage (23%), Benefit: Cost Ratio of NAA (1:2:97).

Keywords: Bougainvillea, cuttings, growth regulators, NAA, IBA

Introduction
The genus Bougainvillea is endemic to South America and was firstly reported in Brazil in 1778 before being introduced to Europe, by French military commander Louis Antoine De Bougainville from Rio De janeiro, Brazil after whom it is being named. They are bushes spread in vines or small ornamental trees. Bougainvillea was first collected by Commerson, a French botanist. Bougainvillea is a genus of native flowering plant in South America, originated from West Brazil to Southern Argentina. Belonging to the family Nyctaginaceae it has ten species, of which three species have got horticultural importance namely, *B. spectabilis*, *B. glabra* and *B. peruviana* (Bhardwaj *et al*., 2020) [1]. Bougainvillea is an evergreen, tropical and subtropical woody, shrubby vine plant which grows as a climber spreading horizontally or hanging downward with slender arching canes with stiff thorns growing even up to 12 m tall. Bougainvillea is a quick-growing shrub and varies in height according to different species and cultivars. The leaves are simple, alternate, roundish, ovate or elliptic-lanceolate. Bougainvillea are armed with stout spines in the stem with the help of which the shrub is able to climb. It has three brightly colored petal-like bracts which give beauty to Bougainvillea. It is the important ornamental shrub, with profuse branching which makes ideal for landscape gardening. (Sharif Hossain *et al*., 2007) [17]. The plant growth regulators stimulate a greater pecentage of rooting and production of more roots in a shorter time in cutting, quicker callus formation and better germination associated with more vigorous growth during initial stages are the major benefits derived from the use of growth regulators in plant propagation.
Bougainvillea can be propagated both by sexual (seeds) as well as asexual (vegetatively) methods, however, cutting, budding, layering, inarching are commercially used for propagation as seed setting is extremely low. The general practice of multiplication for most of the perennial ornamental plants is by the use of vegetative plant parts including stem, leaves and roots.
Adventitious root formation is a key step in vegetative propagation of woody or horticultural species, problems associated with rooting of cuttings frequently result in significant economic losses, preventing growers from realizing the full potential of propagation. The key to overcoming this challenge is the application of exogenous auxin/rooting hormones. The commercially available exogenous auxins that aids the formation of adventitious roots are;

Indole- 3-acetic acid (IAA), Indole-3-butyric acid (IBA) and Naphthalene Acetic acid (NAA). IBA or NAA or combination of both is recommended for rooting of cuttings and are available in liquid, talc, tablet and gel formulations. Other than this (IAA, IBA) naturally occurring auxins favors apical dominance, helps to control xylem differentiation and help in cell division. NAA is a synthetic plant hormone in the auxin family and is an ingredient in many commercial plants rooting horticultural products, it is a rooting agent and used for the vegetative propagation of plants from stem and leaf cuttings, it is also used for plant tissue culture. (Memon *et al.,* 2013) [9].

Materials and Methods

An experiment entitled, "Effect of growth regulators on sprouting and rooting of Bougainvillea hardwood cuttings," was conducted at ornamental plants nursery, Department of Floriculture and Landscape Architecture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The hardwood cuttings 15 cm length, pencil thickness was prepared in January, and quick dip (10 seconds) treatment with different concentrations of IBA (Indole- 3 butyric acid), NAA (Naphthalene acetic acid) were applied. The stock solution of ppm was prepared by dissolving NAA or IBA 1mg/liter in distilled water. IBA and NAA directly does not dissolve in distilled water so ethyl alcohol was used. The hard wood cuttings were treated with growth regulator with different concentrations as given below.

Details of Treatments

The experiment was carried out by planting cuttings in black polythene bags and filled with potting mixture which was prepared by well mixing two part of soil, one part of cocopeat, one part of sand and one part of well rotten FYM. Copper oxychloride was used as a fungicide to check the fungus attack. The experiment was laid out in completely randomized design with thirteen treatments which was replicated three times *viz*., IBA 750 ppm (T1), IBA 1000 ppm (T2), IBA 1250 ppm (T3), IBA1500 ppm (T4), IBA 1750 ppm (T5), IBA 2000 ppm (T6), NAA 750 ppm (T7), NAA 1000 ppm (T8), NAA 1250 ppm (T9), NAA 1500 ppm (T10), NAA 1750 ppm (T11), NAA 2000 ppm (T12), Control (T13).

Results and Discussion

Effect on shoot characters Number of days to sprouting

The treatment T6 (IBA 2000 ppm) recorded minimum days (9.63 days) for first sprouting. This was followed by treatment T12 (10.73 days), T5 (12.73 days), T11 (13.33 days), T4 (13.53 days), T10 (13.93 days) and were at par with each other. However, Maximum days to sprouting (16.27 days) was recorded with treatment T13 (Control). This was followed by treatment T8 (15.00 days), T7 (15.37), T1 (14.80) and were at par with each other. This might be due to the appropriate plant growth regulator and its concentration, which increase the cell division, cell elongation and early differentiation of callus tissue toward the root formation resulted early growth in cutting. During vegetative propagation, early differentiation and growth of leaf buds is dependent on food reserves available in the cuttings, Netam *et al*., (2018) [12]. Similar trend of finding was also confirmed by Bhardwaj *et al*., (2020) [1], Sahariya *et al.,* (2013) [15] and Parmar *et al*., (2010) in Bougainvillea.

Effect of growth regulators on number of leaves

Maximum number of leaves (84.2) were recorded with the treatment T6 (IBA 2000 ppm). This was followed by treatment T12 (83.3), and T5 (76.7). However, significantly minimum number of leaves (46.5) were recorded with the treatment T13 (Control). This was followed by the treatment T7 (59.5). This might be due to the fact that IBA produced healthier lengthy roots and hence absorbed more nutrients and water contents which has resulted in higher number of leaves produced by the plant. Also increase in number of leaves might be due to vigorous growth and early initiation of root induced by the growth regulator which absorbs more nutrients and there by producing more leaves. The results are in conformity with the finding of Netam *et al.,* (2018) [12] in Jasmine, Sahariya *et al.,* (2013) [15] and Kale and Bhujbal *et al*., (1972) [7] in Bougainvillea.

Effect of growth regulators on number of shoots

Maximum number of shoots (3.92) were recorded with the treatment T6 (IBA 2000 ppm). This was followed by treatment T4 (3.42) and were at par with each other. However, minimum number of shoots (2.55) were recorded with the treatment T13 (Control). This was followed by the treatment T8 (3.08) and were at par with each other. This might be due to the fact that, IBA produced healthier lengthy roots and hence absorbed more nutrients and water contents which has resulted in higher number of shoots produced by the plant. Also, auxin enhanced cell division and promotion of protein synthesis which might have resulted in enhanced vegetative growth. The result is in conformity with the findings of Bhardwaj *et al*., (2020) [1], Singh *et al*., (2017) [18] in Bougainvillea.

Effect of growth regulators on fresh and dry weight of shoot (g)

Maximum fresh weight of shoot (11.07 g) was recorded in treatment T6 (IBA 2000 ppm) which was significantly superior than rest of treatment. This was followed by treatment T12 (10.33 g). However, minimum fresh weight of shoot (3.20 g) was recorded with treatment T13 (Control). This was followed by treatment T7 (4.07 g) and at par with each other.

Maximum dry weight of shoot (0.94 g) was recorded in treatment T6 (IBA 2000 ppm). This was followed by treatment T12 (0.90 g) and were at par with each other. However, significantly minimum dry weight of shoot (0.26 g) was recorded with treatment T13 (Control), followed by treatment T7 (0.40 g). This might be due to the fact that, early and fast cell division and cell enlargement with early and easy initiation of roots caused by auxin. Fresh matter accumulation of plant depends upon the vegetative growth parameter *viz*., plant height, spread or average number of branches and it is directly influenced by auxin. The result is in conformity with the findings of Netam *et al*., (2018) [12] in Jasmine, Ganjure *et al.,* (2014) [4] in chrysanthemum, Yeshiwas *et al*., (2015) [21] in rose and Singh *et al*., (2017) [18] in Bougainvillea.

Effect of growth regulators on plant height (cm)

Maximum plant height (84.66 cm) was recorded with treatment T6 (IBA 2000 ppm) which was significantly superior than rest of all treatment. This was followed by treatment T12 (79.33 cm). However, minimum plant height (54.00 cm) was recorded with treatment T13 (Control). This was followed by treatment T1 (61.46 cm). This might be due to the fact that, enhancement of vegetative growth by auxins may have contributed to overall increase in plant height and also the branch length increases with the auxin concentration.

The results are in conformity with the findings of Bhardwaj *et al.*, (2020) [1] in Bougainvillea.

Root Parameters

Effect of growth regulators on days to rooting

The treatment T6 (IBA 2000 ppm) recorded minimum days (15.6 days) for rooting. It was followed by the treatments T12 (16.2 days), which at par with each other. However, significantly maximum days required for rooting (25.9 days) were recorded with the treatment T13 (Control). It was followed by treatment T7 (20.5). This might be due to the fact that, exogenous application of auxin which breaks starch into simple sugars. This is needed to a greater extent for the production of new cells and increased respiratory activity in the regeneration of tissue at the time of initiation of new primordial. The results are in conformity with the findings Mehraj *et al.*, (2013) in Bougainvillea, Kumar *et al*., (2014) [8] in Carnation.

Effect of growth regulators on number of roots per cutting

Maximum number of roots per cutting (26.5) were recorded with the treatment T6 (IBA 2000 ppm). It was followed by treatment T12 (26.0), were at par with each other. However significantly minimum number of roots (8.2) was recorded with the treatment T13 (Control). It was followed by treatment T7 (15.8) and T1 (16.6). This might be due to the effect of IBA as it increases cell wall plasticity and cell division, stimulates callus development and root growth. Also, cuttings treated by auxin with appropriate concentration induces early and better root initiation. Thus, maximum number of roots were produced in those treatment which received maximum concentration of auxin and it might be due to auxin application which initiate early and more root per cuttings. the results are in conformity with the findings Neetam *et al*., (2018) [12] in Jasmine, Bhatt and Chauhan (2012) [2], Ullah *et al*., (2013) [20] in Marigold, Nagaraja *et al*., (1991) [10] in Jasmine.

Effect of growth regulators on length of roots

Maximum length of root (18.75 cm) was recorded with the treatment T6 (IBA 2000 ppm). It was followed by the treatment T12 (17.09 cm) and at par with each other. However, significantly minimum root length (5.94 cm) was recorded in treatment T13 (Control). It was followed by treatment T7 (9.56 cm). This might be due to the fact Increased root length treated with IBA due to the enhanced hydrolysis of carbohydrates, synthesis of new proteins, cell enlargement and cell division induced by the auxins. Auxins initiate synthesis of structural enzyme protein in the formation of adventitious roots. Thus, increasing the root length through the process of acidification. The results are conformity with findings of Chovatia *et al*., (1995) [3], Panwar *et al*., (1994) [13] and Singh *et al*., (2017) [18] in Bougainvillea, Bhatt and Chauhan (2012) [2] in Marigold.

Effect of plant growth regulators on survival percentage (%)

Maximum survival percentage of cuttings (95.33%) were recorded with the treatment T6 (IBA 2000 ppm). It was followed by treatment T4 (88.00%), T1 (82.66%) and were at par with each other. However, minimum survival percentage of cuttings (73.00%) were recorded with T13 (Control). It was followed by treatment T7 (74.00) and were at par with each other. This might be due to maximum number of roots, higher length, thickness and perhaps ability of regenerating further new, fibrous roots from main root, which probably absorb more nutrients and water from the soil and resulted in maximum percentage of survival. The result is in conformity with the findings of Gupta *et al.*, (2002) [6] in Bougainvillea.

Effect of growth regulators on root volume (ml)

Maximum root volume (1.95 ml) was recorded with the treatment T6 (IBA 2000 ppm). It was followed by treatment T12 (1.93 ml) and were at par with each other. However, minimum root volume (1.34 ml) was recorded with T13 (Control) and was significantly minimum than rest of all treatments. It was followed by the treatment T7 (1.61 ml). This might be due to that proper concentration of IBA and type of cutting (hardwood cutting) as the number of roots, length of root and fresh weight of root. The results are in conformity with the findings of Soudagar (2020) [16] in Ixora.

Effect of growth regulators on fresh and dry weight of root (g)

Maximum fresh weight of root (1.54 g) was recorded in treatment T6 (IBA 2000 ppm) and was significantly superior than rest of all treatment. This was followed by treatment T12 (1.41 g). However, significantly minimum dry weight of root (0.31 g) was recorded with treatment T13 (Control). This was followed by treatment T7 (0.85 g).

Maximum dry weight of root (0.40 g) was recorded in treatment T6 (IBA 2000 ppm) and was significantly superior than rest of all treatment. This was followed by treatment T5 (0.35 g). However, significantly minimum dry weight of root (0.14 g) was recorded with treatment T13 (Control). This was followed by treatment T7 (0.22 g) and T1 (0.24 g). This might be due to the fact that, cuttings treated with plant growth regulators help in the better mobilization and translocation downward of primary metabolites for better root formation and nutrient uptake. The results are in conformity with the findings of Singh *et al*., (2017) [18] in Bougainvillea, Singh and Negi (2014) [19] in Tecoma.

Effect of growth regulators on stem girth (cm)

Maximum stem girth (1.13 cm) was observed with the treatment T6 (IBA 2000 ppm). This was followed by treatment T5 (1.02 cm), and were at par with each other. However minimum stem girth (0.81 cm) was observed with the treatment T13 (Control). This was followed by the treatment T7 (0.82 cm), and were at par with each other. This may be due to the fact that IBA produced healthier lengthy roots and hence absorbed more nutrients and water contents. The results are in conformity with the findings of Bhardwaj *et al*., (2020) [1] in Bougainvillea.

Effect of growth regulators on plant spread (cm)

Maximum plant spread (81.57 cm) was recorded with the treatment T6 (IBA 2000 ppm). It is followed by treatment T5 (77.43 cm). However, minimum plant spread (38.83 cm) was recorded with the treatment T13 (Control) which was significantly maximum than rest of all the treatments. It was followed by treatment T7 (43.87 cm). This might be due the fact that, an application of plant growth regulator at different concentration might have enhanced the plant spread by auxins may have contributed to overall increase in plant height by increasing the internodal length as a result of increased cell elongation and faster cell division. Also, the branch length increases with the auxin concentration. These results are in

conformity with the findings of Ranpise *et al*., (2004) [14] in Chrysanthemum, Girisha *et al*., (2012) [5] in Daisy.

Effect of growth regulators on mortality (%)

Minimum mortality (23%) was observed with the treatment T6 (IBA 2000 ppm) which was significantly minimum than rest of all the treatment. It is followed by treatment T12 (28%), T5 (31%). However, maximum mortality (51%) was observed with the treatment T13 (control). It was followed by treatment T7 (50%). This might be due to the fact that, maximum survival percentage of cuttings due to maximum number of roots, higher length, thickness and perhaps ability of regenerating further new, fibrous roots from main root, which probably absorb more nutrients and water from the soil and resulted in minimum mortality percentage. The result is in conformity with the findings Bhardwaj *et al*., (2020) [1] in Bougainvillea.

Effect of different growth regulators on Benefit: Cost ratio

The benefit cost ratio differed significantly between the treatments due to application of growth regulators. The treatment consisting of NAA 2000 ppm resulted in maximum benefit cost ratio, which was found to be 1:2:97 while minimum 1:2:04 benefit cost ratio was observed in control. This is mainly due to the fact that NAA has low market cost and also profitable than the market cost of IBA and also NAA 2000 ppm has higher survival percentage of cuttings after IBA so that's why significant result found in NAA 2000 ppm than other treatments. In general, NAA 2000 ppm have been found to induce better root system in Bougainvillea cuttings. The basis for this may be enhancement of hydrolysis of nutrient reserves (mainly starch) by auxin treatments. According to (Nanda, 1975) [11] enhanced hydrolysis activity in the presence of exogenously applied hormones was responsible for the increased rooting in auxin treated cuttings

Table 1: Effect of plant growth regulators on sprouting of Bougainvillea hardwood cuttings.

Treatments	Days to sprouting	Number of leaves	Number of shoots	Fresh weight(g)	Dry weight(g)	Stem girth (cm)	Plant spread	Mortality (%)	B:C ratio	Plant height (cm)
T1	14.80	61.8	2.79	4.27	0.44	0.88	45.63	44	1:2:53	61.46
T2	14.33	64.8	3.12	6.00	0.48	0.95	52.53	41	1:2:54	65.53
T3	14.00	70.7	3.19	7.40	0.80	0.97	55.67	39	1:2:56	69.46
T4	13.53	72.3	3.42	8.60	0.82	0.99	71.80	36	1:2:51	73.26
T5	12.73	76.7	3.64	9.80	0.84	1.02	77.43	31	1:2:55	75.26
T6	9.63	84.2	3.92	11.07	0.94	1.13	81.57	23	1:2:54	84.66
T7	15.37	59.5	2.66	4.07	0.40	0.82	43.87	50	1:2:46	60.66
T8	15.00	63.7	3.08	5.33	0.47	0.93	51.37	42	1:2:71	62.66
T9	14.37	65.5	3.13	7.00	0.78	0.96	53.57	41	1:2:76	67.6
T10	13.93	71.6	3.28	8.07	0.81	0.98	62.50	37	1:2:81	72.00
T11	13.33	73.2	3.35	9.60	0.84	0.99	75.63	34	1:2:89	74.13
T12	10.73	83.3	3.37	10.33	0.90	1.09	78.50	28	1:2:97	79.33
T13	16.27	46.5	2.55	3.20	0.26	0.81	38.83	51	1:2:04	54.00
C.D at 1%	1.141	2.694	0.518	0.194	0.056	0.33	4.001	2.32	-	4.609
SE(m)	0.290	0.686	0.132	0.304	0.014	0.128	1.018	0.59	-	1.173

Table 2: Effect of plant growth regulators on rooting of Bougainvillea hardwood cuttings

Treatments	Days to rooting	Number of roots	Length of roots (cm)	Survival percentage (%)	Root volume	Fresh weight (g)	Dry weight (g)
T1	20.3	16.6	9.77	82.66	1.63	0.90	0.24
T2	19.9	19.0	11.04	84.66	1.66	0.95	0.24
T3	18.6	19.8	12.49	87.33	1.68	1.17	0.28
T4	17.8	23.0	13.72	88.00	1.75	1.25	0.31
T5	16.5	25.3	15.64	92.00	1.86	1.33	0.35
T6	15.6	26.5	18.75	95.33	1.95	1.54	0.40
T7	20.5	15.8	9.56	74.00	1.61	0.85	0.22
T8	20.1	17.9	9.90	84.33	1.65	0.93	0.24
T9	19.6	19.7	11.75	87.00	1.67	1.15	0.25
T10	17.8	20.2	13.19	87.66	1.74	1.19	0.29
T11	17.5	23.0	15.25	91.66	1.81	1.28	0.34
T12	16.2	26.0	17.09	92.66	1.93	1.41	0.35
T13	25.9	8.2	5.94	73.00	1.34	0.31	0.14
C.D at 1%	1.288	1.73	1.032	6.912	0.008	0.040	0.018
SE(m)	0.328	0.44	0.263	1.759	0.023	0.010	0.005

Conclusion

From the result of an experiment conducted to study the, effect of growth regulators on sprouting and rooting of Bougainvillea hardwood cuttings. Following conclusion could be drawn. On the basis of findings reported in present investigation the effect of plant growth regulators on shoot growth, root growth, survival percentage (%) and mortality percentage (%) of Bougainvillea hardwood cuttings was found to be significant. In respect of different root, shoot, and growth parameters, *i.e*. Days to sprouting (9.63), number of leaves (84.2), number of shoots (3.92), fresh and dry weight of shoot (11.07 g), (0.94 g) respectively, plant height (84.66 cm), days to rooting (15.6),number of roots per cutting (26.5), length of main root (18.75 cm), survival percentage of rooted cuttings (95.33%), root volume (1.95 ml), fresh and dry weight of cuttings (1.54 g), (0.40 g) respectively, stem girth (1.13 cm), plant spread (81.57 cm), mortality percentage (23%) better performance of cuttings was observed in

treatment T6 (IBA 2000 ppm) among different treatments. The above conclusion was based on the finding of experimental period of study.

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