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A review on effect of IBA and NAA and their combination on the rooting of stem cuttings of different ornamental crops

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Abstract
The objective of the current review is to review and identify the research on the effect of IBA, NAA and their combination effect on shooting and root growth of ornamental crops specially African marigold (*Tagetes erecta* L.) cuttings. Factors affecting rooting of ornamental crops cuttings can be internal or external factors. Internal factors affecting rooting of cuttings include the amount of stored food in cuttings, the age and maturity of tissue, the formation of callus and adventitious roots and the presence of leaves and buds on cuttings. The external factors include rooting media, chemical and hormone treatments, light, temperature, mechanical treatment and mist spray. IBA, NAA is one of the most important factors for cutting production. Types of rooting hormone have significantly influenced the rooting and vegetative growth of cuttings. The concentration of rooting hormone depends on the species, type of cuttings, growing conditions, season of the year and the cost effectiveness of the rooting hormone components. Choosing the most suitable concentration of rooting hormone for the achievement of a successful plant production is very important which is significantly helpful for the farmers for off season production of ornamental crops through cuttings

Keywords: Rooting hormone; Ornamental Crops; Shooting; Stem cutting; Rooting; IBA; NAA

Introduction
Auxin is used mostly for better rooting in stem cuttings for many flowers which increase survival percentage and better rooting. One of the many approaches has been the application of plant growth regulating chemicals to bring about a change in the growth of roots and shoots of some horticultural crops of ornamental importance. IBA and NAA are used to induce rooting has been practicing since earlier time to ensure success of rooting in cutting and better establishment of plants. In this review an attempt has been made to present the work done earlier in the aspect of stem cutting with the use of auxin, that enhance rooting and shooting.

Objectives
The brief review of various experimental findings pertaining to different aspect of the present study has been reviewed under following heads.

- Effect of IBA and NAA and their combination on shooting and root growth in *Tagetes spp*.
- Effect of IBA and NAA and their combination on shooting and root growth in other flower and ornamental crops.

Effect of IBA and NAA and their combination on shooting and root growth in *Tagetes spp*.
Bhatt and Chouhan (2012) [7] studied effect of different auxin and their level with combination on rooting of African Marigold (*Tegetes erecta* L.) and result revealed that maximum average number of roots per cutting after 20 and 30 days was 40.53 and 58.79, respectively under the treatment at IBA + NAA 150 ppm. The average length of stem per cutting was maximum (6.1 and 15.33 cm) under IBA + NAA 150 ppm after 20 and 30 days, respectively. The average length of root per cutting was recorded maximum (4.6 cm) under NAA 200 ppm after 20 days and (5.51 cm) under IBA + NAA 150 ppm after 30 days.
Ullah *et al*. (2013) [45] reported that the maximum (82.4) number of roots were found in 400 ppm of IBA whereas, maximum root length was recorded (6.5 cm) in 100 ppm of IBA but increasing concentration of IBA up to 400 ppm. Thus, decreasing the root length in African Marigold.
Majumder *et al.* (2014) [18] reported that in shoot tip culture of Marigold cv. Pusa Narangi Gainda half-strength MS medium supplemented with 1.0 mg/l NAA and 1.0 mg/l IBA was

Observed to be efficient for rooting (87.33%). While MS medium supplemented with low auxin (0.2 mg/l NAA) was reported highest shoot multiplication (10.15 shoots/ explant). Sharma (2014) investigated that the root length (9.14 cm) as well as root spread (4.53 cm) was maximum in 200 ppm of IBA. Whereas, the number of roots (44.43), fresh weight (0.71 gm) and dry weight of roots (0.079 gm) was maximum in 400 ppm of IBA and the rooting percentage was maximum (92.80%) under IBA+NAA 200 ppm in stem cuttings of Marigold.

Effect of IBA and NAA and their combination on shooting and root growth in other flower and ornamental crops

Cooper (1935) treated cuttings of Bougainvillea to various concentrations of IAA, IBA and NAA and found that the IAA at 500 ppm gave best results, followed by NAA 500 ppm. Singh and Bhatnagar (1955) [39] observed that the maximum rooting (90%) in the cuttings of *Jasminum grandifolium* when treated with 500 ppm of NAA as compared to control (30%). Lingaraj and Chandrasekhariah (1961) [17] reported that the IAA and IBA separately at 3000 ppm induced profuse rooting, but combinations of IAA, IBA and NAA were generally more effective at 1000 or 2000 ppm (66%) in *Antirrhinum majus*.

Bael and Herregods (1970) [4] reported that treatment with 3 per cent NAA enhanced rooting in *Ficus elastica*, with better rooting in leaf cuttings than in apical stem cuttings with 8 leaves.

Nathulal *et al.* (1972) [23] observed that in Bougainvillea the best rooting behavior was found in IAA 500 ppm followed by NAA 500 ppm. The number of rooted and sprouted cuttings were 18.3 and 16.3 out of 20 cuttings in IAA 500 ppm and NAA 500 ppm, respectively.

Maury a *et al.* (1974) [19] treated cuttings of Bougainvillea cv. Mary Palmer with IAA, NAA or IBA each at 100-400 ppm for 12 hours. Best results were obtained with IAA 400 ppm, followed by NAA 400 ppm. The rooting percentages were 72 and 70.83 for IAA 400 ppm and NAA 400 ppm respectively.

El-Shafie *et al.* (1976) [10] reported that 50 ppm NAA produced the best results in rooting of Rose cv. Perle von Aalsmeer.

Hartley *et al.* (1978) [15] reported that spraying in the bases of Carnation cuttings with 0.5% IBA + 0.5% NAA resulted in best rooting followed by 0.5% IBA + 0.125% NAA and 0.2% IBA + 0.125% NAA.

Singh (1981) [40] reported that *Ixora banduca* tip cuttings were treated with IBA and NAA, each at 1000-4000 ppm and found that the IBA at 2000 ppm gave highest rooting percentage (97.5), followed by NAA at 1000 ppm (95 per cent).

Uitermark (1984) reported that rooting was best in Carnation after a basal dip in NAA at 380 ppm for 3 seconds or at 250 ppm for 10 minutes.

Rak and Nowak (1988) [26] observed greatly enhanced root formation in *Antirrhinum majus* cuttings treated with 500 ppm NAA and a mixture of NAA + IAA (2000 + 500 ppm).

Shenoy (1992) [31] reported that the application of IBA at 3000 ppm resulted the highest survival of rooted cuttings (48.97%) followed by 300 ppm NAA (41.11%) in the basal woody cuttings of Damask Rose.

Singh (1999) [33] stated that a quick dip of Carnation cuttings of 10-15 cm length with 4-5 pairs of leaves in 500 ppm NAA promoted rooting.

Wassner and Ravetta (1999) [48] reported that the stem cuttings treated with 0.1 and 1.6% of IBA resulted 64% more rooting from control in Gum weed (*Grindelia chiloensis*). Nagaraja *et al.* (2001) reported that hardwood cuttings of *Jasminum grandiflorum* had the highest regenerative capacity with 3000 ppm IBA (100%) and the lowest was in semi hardwood cuttings (73.33%).

Singh (2001) [32] studied the effects of auxins on the rooting and survival of Jasmine (*Jasminum sambac*) and they observed that IBA at 2000 ppm was recorded highest rooting percentage, root length, root number and root fresh weight. While maximum survival percentage in cuttings treated with 1000 ppm NAA.

Swamy *et al.* (2002) [42] observed that the highest rooting percentage (83.3%) were found in 500 ppm NAA followed by 250 ppm IBA. The maximum rooting percentage (80%) and root length (11.3 cm) were found in 250 ppm IBA followed by 250 ppm NAA. Whereas, the maximum number of roots (17.6) were found in 500 ppm IBA followed by 500 ppm NAA in juvenile cuttings of *Robinia pseudoacacia*. Further they reported in *Grewia optiva*, the maximum root length (10.75 cm) and number of roots (16.33) were found in IBA 750 ppm followed by NAA 750 ppm.

Blythe *et al.* (2004) [8] studied that the rooting of stem cuttings of four tropical ornamentals treated with auxin by basal quick-dip method with the concentration of 4920 µM IBA + 2685 µM NAA. The terminal cuttings of *Aglaonema modestum* S. produced 9.5 roots per cutting and total root length of 38.6 cm, while untreated cuttings produced 6.1 roots per cutting and total root length of 27.0 cm. Two node cuttings of *Gardenia augusta* L. produced 9.1 roots per cutting and total root length of 31.1 cm while untreated cuttings produced similar or lesser results. Terminal cuttings of *Ficus benjamina* L. produced total root length of 40.0 cm while untreated cuttings produced total root length of 33.2 cm. Cuttings of *Hedera helix* L. produced 8.3 roots per cutting and total root length of 25.7 cm.

Grewal *et al.* (2005) [13] studied in stem cuttings of *Dendranthema grandiflora* cv. Snowball. The rooting percentage (88.7%) and number of roots (8.67) were observed maximum in IBA 400 ppm.

Swetha (2005) [43] reported that the IBA at 2000 ppm was found better induction of rooting (66.66%) as against the control (15.33%) in Indian lavender (*Bursera delpechiana*).

Bharmal *et al.* (2005) [6] observed that the IBA 2000 ppm as a quick dip method along with 2 sprays of 10 ppm IBA after 30 and 60 days of planting of cuttings was significantly superior treatment over the other (1000, 2000 and 3000 ppm) IBA treatments and control by recording the highest number of primary roots (20.85), survival percentage (96.57%) after 30 days of planting of cuttings in Chrysanthemum cv. Sonali Tara.

Vinaykumar *et al.* (2008) [46] reported that the highest percentage of rooting was observed in IBA+NAA 2000 ppm (63.73%) followed by IBA+NAA 1500 ppm in stem cuttings of *Thunbergia grandiflora*.

Baul *et al.* (2009) [5] reported that the application of 0.2% IBA resulted in maximum number of roots (4.33) as well as length of roots (5.88 cm) in the cuttings of Trumpet flower tree (*Stereospermum suaveolens*).

Singh *et al.* (2011) [36] reported that the length of sprout (18.77 cm) and number of roots (21.22) were found maximum in 3000 ppm of IBA and length of root was maximum (15.32 cm) in 5000 ppm concentration of IBA in stem cuttings of *Bougainvillea glabra*.

Waseem *et al.* (2011) [47] reported that the shoot initiation (80.00%), shoot per explants (3.2), length of shoots (3.4 cm),

number of leaves (9.5) and nodes (4.5) were recorded maximum in MS media supplemented with 0.5 mg/l NAA whereas maximum root initiation percentage (100%), roots per plantlet (14.3) and root length (9.0 cm) was obtained in half strength MS media supplemented with 0.2 mg/l Indole butyric acid (IBA) in shoot tip culture of Chrysanthemum plantlets (*Dendranthema morifolium* L.).

Zepa *et al.* (2011) [52] reported that in pot Marigold (*Calendula officinalis*) explants were cultured on Murashige and Skoog containing different concentrations of IAA, 2,4-D, 6-benzylaminopurine (BAP) and naphthalene acetic acid (NAA). The most efficient shoot and callus formation was obtained from MS medium with 1 mg NAA and 0.1 mg BAP/l.

Rahbin *et al.* (2012) [24] was recorded in stem cuttings of Night Jamine (*Cestrum nocturnum*), the rooting percentage (72.5%), number of roots (10.2), root length (8.2 cm) fresh weight (0.86 g) and dry weight (0.09 g) of root significantly better in IBA 4000 ppm.

Ganjure *et al.* (2012) [11] showed that the response of IBA on rooting of cuttings in Chrysanthemum, the days to sprouting (8.60), days to rooting (9.33) were found minimum in IBA 1000 ppm. Whereas, the fresh weight (1.86 g) and dry weight of roots (0.16 g), fresh weight (1.87 g) and dry weight (0.17 g) of shoots were found to be higher in concentration of IBA 1000 ppm.

Susaj *et al.* (2012) [41] reported that the maximum survival percentage in two different cultivars of *Rosa spp.* (91% and 89%, respectively) by using IBA 500 ppm. Whereas, maximum number of roots (50 and 47 roots) and the longest roots (31 and 28 cm) were recorded by using IBA 1000 ppm.

Abu-zahra *et al.* (2013) [2] reported that the 3000 ppm NAA was recorded highest rooting percentages in Hedera cuttings, while best results were obtained by 4000 and 1000 ppm NAA in Gardenia and Syngonium cuttings, respectively.

Singh *et al.* (2013) [37] reported that the highest number of roots per cutting (91.00) was recorded in NAA 300 ppm while rooting percentage (76.53), length of roots per cutting (23.76 cm), fresh weight (6.06 g) and dry weight (1.33 g) of roots were higher in IBA 100 ppm and the maximum length of sprout per cutting (190.00 cm) was observed under IBA 300 ppm in stem cuttings of Night Queen (*Cestrum nocturnum* L.).

Haixia *et al.* (2013) [14] reported that the highest survival percentage of Rose cuttings treated with NAA 250 ppm + IBA 250 ppm (95.33%) followed by IBA 250 ppm.

Sahariya *et al*. (2013) [28] studies that the IBA at 2000 ppm was superior for the percentage of rooted cuttings (63.33%), number of roots (30.00), length of roots (12.85cm) and dry weight of roots (0.43g) per cutting after two month of planting in Bougainvillea (var. Thimma) cuttings.

Mehraj *et al.* (2013) [20] reported that the 1000 ppm IBA was performed best for days to first rooting (4.0), days to first sprout bud initiation (5.3), number of sprouted bud/cutting (3.6), number of leaves/cutting (35.2), length of sprout (15.0 cm), number of branches/cutting (4.7), number of root/cutting (64.2), number of sub root/cutting (25.8), longest root length (33.2 cm), longest root diameter (0.51 mm), rooting percentage (100%), survival percentage of rooted cuttings (100%) in *Bougainvillea spectabilis* cuttings.

Ghofrani *et al.* (2013) [12] studied that effect of IBA on rooting of cuttings in Carnation flowers (*Caryophillium aromaticus*) in three environments various acidic. The number of roots (15.0), fresh weight (41 mg) and dry weight of roots (6 mg) observed maximum in IBA 400 ppm with sulfuric acid while maximum length of root (14 cm) observed in IBA 600 ppm with acetic acid.

Kumar *et al.* (2014) [16] investigated that the effect of different auxin (IAA, NAA and IBA) and types of cutting significantly affect the rooting traits. In the basal cuttings earliest rooting (18.69 days), highest rooting percentage (58.70%), number of roots (13.18), root length (12.26 cm) and highest fresh (4.93 g) and dry weight of roots (45.08 mg) were obtained with NAA 500 ppm and tip cuttings of Carnation responded better in rooting-characteristic of Carnation than basal cuttings, and recorded highest rooting percentage (85.26%), number of roots (18.36), longest roots (14.81cm), and highest fresh and dry weight of roots (6.85 g and 68.02 mg), respectively, observed with NAA 500 ppm in Carnation (*Dianthus caryophyllus* L.).

Yan *et al.* (2014) [50] observed that NAA had positive effect on rooting at the concentration of 200 ppm compared to other concentrations at 30 days after planting. Among the three (10, 20 and 30 min.) soaking durations, 20 minutes (min) of 200 ppm NAA resulted in higher percentages of rooting (97.2%), larger numbers of adventitious roots (35.4) and heavier root dry weight (0.28 g) per cutting. This concentration of NAA was better rooting ability for Whip Grass cuttings and might serve as a good marker for rooting ability in cuttings.

Sayedi *et al.* (2014) [29] reported that the rooting percentage (72.3%), length of roots (36 mm) and number of roots (9.0) observed maximum with IBA 4000 ppm in hard wood cuttings of *Bougainvillea glabra* L.

Rahdari *et al.* (2014) [25] showed that the highest root fresh weight (5.40 g), root dry weight (0.65 g), root length (17.3 cm) is regard to the treatment of combined density NAA 2000 ppm + IBA 1000 ppm that had the meaningful difference in statistical level in stem cuttings of *Cordyline terminalis*

Wazir (2014) studies that the effect of NAA and IBA on rooting of Camellia cuttings, the rooting percentage (84.94%), length of root (18.30 cm) were found more under 1000 ppm IBA in hardwood cuttings whereas maximum number of roots (14. 54) was found more under 1000 ppm IBA in semi hardwood cutting of *Camellia japonica*.

Singh and Negi (2014) [34] observed that the length of sprouts (10.18 cm), diameter of sprout (0.26 cm), number of leaves on new growth (5.59), number of primary roots (18.66%), length of root (10.53 cm), diameter of root (0.11 cm), fresh weight (0.79 gm) and dry weight of root (0.094 gm) were found maximum in 50 cm long cuttings treated with 1500 ppm concentration of IBA in stem cuttings of *Ticoma stans* L.

Singh *et al* (2014) [34] observed that the among treatments, the highest number of roots per cutting (43.00), length of roots per cutting (9.28 cm), diameter of root per cutting (1.67 mm), percentage of rooted cutting (88.00%), number of sprouts per cuttings (4.34) and the minimum (20.66) days taken to callus formation were noticed in 1400 ppm IBA concentration in stem cuttings of Golden Duranta.

Abbas *et al.* (2015) [1] reported that the maximum number of roots (30.25) were noted in IBA 2000 ppm, whereas, the control produced the least number of roots (16.0) in stem cuttings of Rose cv. Bajazzo.

Yeshiwas *et al.* (2015) [51] reported that the number of roots (54.2), root length (11.29 cm), shoot length (14.4 cm), fresh weight of shoot (2.05 g), dry weight of shoot (0.61 g) and dry weight of root (0.21 g) were recorded maximum under IBA 1000 ppm whereas fresh weight of root (0.90 g) is highest in IBA 1500 ppm in stem cuttings of Rose.

Akhtar *et al.* (2015) [3] investigated that IBA 450 ppm concentration produced maximum shoot length (10.67 cm),

shoot dry weight (3.02 g), number of roots (14.00), root length (11.90 cm) and root dry weight (0.50 g) in stem cuttings of *Rosa centifolia*.

Nasri *et al*. (2015) [22] investigated that application of different levels of 0, 500 and 1,000 ppm (quick dip method for 20 s) of indole butyric acid (IBA) and 12 wild genotypes (including: Kurdistan-1 to Kurdistan-12) highest rooting (79.56%) and callus production (69.08%), number of roots (8.33), fresh weight of root (361.80 mg) and dry weight of root (244.74 mg) were recorded in Kurdistan-5 genotype with 1,000 ppm IBA. The maximum root length (5.84 cm) was observed in Kurdistan-5 genotype with 500 ppm IBA that showed a significant difference compared to the control treatment (0.96 cm). The highest number of leaves (7.33 at 500 ppm IBA) and number of buds (5.00 at 1,000 ppm IBA) were recorded in Kurdistan-1 genotype in cuttings of *Rosa damasce*.

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