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Effect of different rooting hormones and growing media on pot plant production of marigold (*Tagetes erecta* L.) cv. Bidhan marigold 2

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Abstract
The present study entitled "Effect of different rooting hormones and growing media on pot plant production of marigold (*Tagetes erecta* L.) cv. Bidhan marigold 2" was carried out during the year 2022-23 in the shade net of Horticultural Research farm at Pt. KLS College of Horticulture and Research Station, Rajnandgaon, (C.G.). The investigation was framed in Factorial Completely Randomized Design with 21 treatments which were replicated thrice. There were 2 factors, first factor with 7 levels of different rooting hormones *viz*, Distilled water (H1) as control, IBA 200 ppm (H2), IBA400 ppm (H3), NAA 200 ppm (H4), NAA 400 ppm (H5), IBA100+NAA100 ppm (H6), IBA200+NAA200 ppm (H7) and second factor with 3 levels of Growing media i.e., Soil (M1), Soil: FYM (1:1) M2, Soil: Vermicompost (1:1) M3. The interpretations were recorded on various Root parameters. Among rooting hormones IBA 400 ppm (H3) recorded minimum days to rooting (8.88 days), highest rooting success (88.31%), maximum fresh weight of root (0.747 g), dry weight of root (0.071 g), plant height (55.62 cm), plant spread (36.54 cm) and survival percentage (79.05%). In case of growing media Soil: Vermicompost (1:1) out performed in all the parameters, minimum days to rooting (10.38 days), highest rooting success (80.42%), root length (8.22 cm), fresh weight of root (0.635 g), dry weight of root (0.056 g), plant height (51.81 cm), plant spread (34.76 cm) and survival percentage (84.29%).

Keywords: Marigold, stem cutting, Bidhan marigold 2, rooting hormones, growing

Introduction
Marigold (*Tagetes erecta* L.) belongs to the family Compositae. It is native to Central and South America, especially Mexico. In India, marigold was introduced by the Portuguese in the 16th century and it became popular and spread all over the country because of its wide adaptability. Marigold is the most popular flower among the numerous loose flowers grown throughout India. Flower is preferably used loosely and enjoys high demand in the Indian market for its aesthetic and industrial value. Flowers are traditionally used as offerings in temples, churches, festivals, beautification and landscape. It is highly suitable for pot culture, bedding purposes and window boxes

Marigold is generally propagated by seed, but uniform sized commercial grade flower production is possible only when the plant is propagated through vegetative means. Therefore, vegetative propagation, such as cutting is the optimum approach for mass replication of planting material that is true to type is essential for ensuring both the quality and field of marigold flowers. Normally, seeds are used for propagation during summer cultivation (seed planting in winter), however, considering the needs of the regional farmers in Chhattisgarh and the scarcity of seeds during this time, it may be possible to experiment with stem cuttings throughout the winter.

Rooting of cuttings is significantly affected by the type of cuttings used for propagation; processes of regeneration and multiplication during propagation are primarily dependent on internal and external factors (Farooqi *et al*., 1994) [18]. Auxin is widely known for stimulating cutting roots (Hartmann *et al*., 2002) [19]. IBA and NAA are the most commonly used auxins for rooting stem cuttings and tissue-culture micro cuttings nowadays (Zimmerman and Wilcoxon, 1935). Auxin is essential for the start of adventitious roots on stems and it has been demonstrated that divisions of the first root initial cell are dependent on either applied or endogenous auxins (Gaspar *et al*., 1988; Stromquist and Hansen, 1980) [21, 22]. IBA has been found to exist naturally.

The natural auxins in the cuttings and a synergistic substance such as a diphenol are necessary for the development of root primordium cells. These substances lead to the synthesis of ribonucleic acid (RNA), which act upon root primordium imitation (Hartman *et al*., 2002) [19].

A suitable growing media is also crucial in rooting due to its specific qualities for storing moisture, Ventilation, discharge or capillary action and recycling potential (Vendrame *et al*., 2005) [17]. Among the numerous media, vermicompost and FYM are most commonly employed in tropical and subtropical environments. The presence of suitable nutrients, moisture holding ability, permeability and lump-forming capability in media improves root and shoot growth, which eventually results in high crop production.

FYM is a component of commercial potting material. Increases cation exchange capacity, improves water holding capabilities and provides the necessary nutrients. The composting of organic waste preserves nutrients; many of them can be seen on or integrated into the humic particles of the decomposed material. According to Bachman and Metzger (2007) [23], composts quickly enhance nutrient absorption, assimilation and hormone-like activity.

Vermicompost functions as a soil conditioner and an excellent, nutrient-rich organic fertilizer since it includes water-soluble nutrients. It has specific characteristics such as fertility, pH, water usage effectiveness, substrate physical properties, microbial activity and organic matter components that may be responsible for the plant's better growth. Vermicompost has a relatively higher concentration of carbon, nitrogen and mineral resources, which is advantageous to plants. Utilizing such nutrients helps plants to develop molecules for better growth and a stronger ability to fight off diseases (Ali, 2014) [3].

Materials and Methods

The experiment was conducted at shade net of Horticulture Research cum Institutional Farm. Department of Floriculture and Landscape Architecture, Pt. K.L.S. College of Horticulture and Research Station, Pendri, Rajnandgaon (C.G.). Rajnandgaon is located in the Chhattisgarh plains at a latitude of 21.100 N and a longitude of 81.030 E, with a mean sea level elevation of 307 meters.

The experiment was done during the year 2022-23 at shade net of Horticultural cum Institutional farm, Pt. K.L.S. College of Horticulture & Research Station Rajnandgaon (C.G.). The experiment was laid out in the Factorial Completely Randomized Design (FCRD) with 21 treatments replicated three times. There were 2 factors under this experiment, first factor was Rooting hormones. Distilled water used as control, IBA 200 ppm, IBA 400 ppm, NAA 200 ppm, NAA400 ppm, IBA100 ppm+NAA100 ppm, IBA200 ppm+NAA200 ppm and the second was Growing media Ratio in Volume Bases. Soil, Soil: FYM (1:1), Soil: Vermicompost (1:1)

Preparation of cuttings the experiment materials, which comprised 8-10 cm terminal shoot cuttings, were taken from two month old plant. Each cutting had a smooth cut applied to the distal end and Soil is cheaply available, economic and manageable. The media were mixed as per the treatment combination. Filling of Polybag, black polythene bags size (8 x 10 inch) with thickness of 200 gauge were used in this experiment and filled with the different growing media comprising of alone Soil, Soil: FYM 1:1 and Soil: Vermicompost 1:1.

Application of plant growth regulators

The stock solution is dissolved in distilled water to get the required ppm concentration of the solution for each treatment. Terminal shoot cuttings of uniform length and diameter of marigold were dipped for two minutes as per treatments. The cuttings under control were dipped in distilled water and soil instead of plant growth regulators. According to the treatment, treated cuttings were planted in various growing media-filled black polybags. Single cutting was planted in single polybag. Planted cuttings were treated with carbendazim 0.2% to avoid the occurrence of fungal infections.

Result and Discussion Days to rooting

All the different concentrations of rooting hormones showed significant differences for days to rooting, the minimum number of days taken to rooting (8.88 days) was recorded with IBA 400 ppm (H3), followed by (9.62 days) IBA 200 + NAA 200 ppm (H7), while the highest number of days taken to rooting (13.64) recorded in control (H1). Among different growing media, the minimum number of days (10.38 days) taken to rooting was recorded with Soil: Vermicompost (1:1), which was followed by (10.66 days) Soil: FYM (1:1), while the highest 10.91 days were recorded in soil media.

The interaction of rooting hormones and growing media significantly decreases the number of days to rooting. It was observed that the minimum number of days taken to rooting (8.40 days) was observed in treatment combination IBA 400 ppm along with Soil: Vermicompost (1:1), followed by (9.06 days) IBA 400 ppm along with Soil: FYM (1:1), while the highest (13.80 days) for rooting was observed in distilled water with soil as growing media.

The interaction effect between rooting hormones and growing media had significant effect on days to rooting. It might be due to the effect of rooting hormones which enhanced the hydrolysis activity when hormones are exogenously supplied to cuttings with appropriate growing medium combinations which provide improve water relationship nutrients retention allow free air movement retain moisture and nutrient for growth of roots. Hence it decreases the days to rooting.

Rooting success

Rooting success was significantly influenced by different concentrations of rooting hormones, maximum rooting success (88.31%) was found at IBA 400 ppm (H3), followed by (86.01%) IBA 200 ppm (H2), while the lowest rooting success (62.38%) were obtained in control (H1). The effect of growing media on rooting success was found to be statistically significant. The media Soil: Vermicompost (1:1) provided the highest (80.42%) rooting success in the various growing media, followed by (77.90%) Soil: FYM (1:1), while the sole soil had the lowest proportion of successful rooted cuttings (74.77%).

The interaction of rooting hormones and growing media significantly increases rooting percentage. The highest rooting (91.93%) was observed in treatment combination IBA 400 ppm along with Soil: Vermicompost (1:1), followed by (88.43%) IBA 200 ppm along with Soil: Vermicompost 1:1, while lowest rooting (60.07%) distilled water along with soil media.

The interaction between rooting hormones and growing media significantly increases the rooting success it might be due to in liquid formulations of auxin and properly growing media combination which evoke the most effective rooting response;

also vermicompost provides good moisture retention and the presence of humic acids and humates in vermicompost, which also includes growth hormones like auxin, cytokinins and gibberellins. Ultimately it increases the rooting success of cuttings.

Root Length (cm)

The effect of different concentrations of rooting hormones was found to be significant in terms of root length. Maximum root length (9.42 cm) was observed in cuttings treated with IBA 200 ppm (H2), followed by (8.75 cm) NAA 200 ppm (H5), while the lowest root length (6.00 cm) was shown by control (H1) among all the treatments. Growing media had a statistically significant impact on the average length of roots per cutting. Soil: Vermicompost (1:1) gave the highest root length (8.22 cm), followed by (7.86 cm) Soil: FYM (1:1), while the lowest (7.37 cm) root length was observed in soil alone. The interaction of rooting hormones and growing media significantly increases root length. Maximum root length (10.30 cm) was found in treatment combination IBA 200 ppm with Soil: Vermicompost (1:1), followed by (9.78 cm) IBA 200 ppm along with Soil: FYM (1:1), while the lowest root length (5.56 cm) was observed in without treated cuttings planted in soil.

Root length was significantly influenced by combination of rooting hormones and growing media. This could be due to rapid auxin translocation, which promotes enzymatic activity during the formation of adventitious roots, as well as the medium's higher water holding capacity and aeration to elongate roots. Vermicompost in medium enhances microbial activity and biomass, both of which are important components of nutrient cycling and the generation of plant growth regulators may result in longer roots.

Fresh weight of root per cutting (g)

Maximum fresh weight (0.747 g) was obtained under IBA 400 ppm (H3), which was found statistically at par with (0.711 g) NAA 400 ppm H5, whereas minimum fresh weight (0.448 g) was observed in cuttings treated with distilled water (H1). The effect of different growing media on fresh weight of root found statistically similar to each other. Maximum fresh weight (0.635 g) obtained in Soil: Vermicompost (1:1), followed by (0.599 g) Soil: FYM 1:1, while the minimum fresh weight (0.593 g) was obtained in soil alone.

The interaction of rooting hormones and growing media found significant effect on fresh weight of root. Maximum fresh weight of root (0.770 g) was found in treatment combination of IBA 400 ppm along with Soil: Vermicompost (1:1), which was statistically at par with (0.760 g) NAA 400 ppm along with Soil: Vermicompost (1:1), while the minimum fresh weight (0.433 g) was observed in distilled water along with soil. The combine effect of rooting hormones and growing media had positive effect on fresh weight of root this could be due to auxin's increased enzyme activity and hormone transfer during cell elongation and division associated with vermicompost rich source of macro and micronutrients, which improved the availability of these nutrients in an accessible form resulting in a greater number of roots and root length which is directly correlated with the fresh weight of roots.

Dry weight of root per cutting (g)

The maximum dry weight (0.071 g) was obtained at IBA 400 ppm (H3), followed by (0.069 g) NAA 400 ppm (H5), while the lowest (0.035 g) dry weight was observed in control (H1). The effects of different growing media were found to be statistically significant. Among them, Soil: Vermicompost (1:1) gave the highest dry weight of root (0.056 g), which was statistically at par with Soil: FYM (1:1) and Soil (0.053 and 0.052 g), respectively.

The combination of rooting hormones and growing media had a significant impact on the dry weight of the root. The maximum dry weight (0.074 g) was obtained at treatment combination IBA 400 ppm along with Soil: Vermicompost (1:1), followed by (0.071 g) NAA 400 ppm with Soil: Vermicompost (1:1), while the minimum (0.034 g) dry weight was found at distilled water along with soil.

The use of different rooting hormones, growing media and their combinations enhanced the dry weight of the root. It might be due to a higher rate of photosynthetic supply from source to sink and the impacts of plant growth regulators and vermicompost-rich sources of macro- and micronutrients may be responsible for the rise in dry weight of roots.

Plant height (cm)

Among different concentrations of rooting hormones, IBA 400 ppm (H3) gave a significantly maximum plant height (30.99, 51.96 and 55.62 cm) at 30, 60 and 90 DAP, respectively, which was at par with (30.63, 48.60 and 52.86 cm) NAA 400 ppm (H5) at 30, 60 and 90 DAP, respectively, while minimum plant height was recorded in control (H1) treatment (21.46, 32.80 and 38.38 cm) at 30, 60 and 90 DAP, respectively. The use of various growing media, Soil:

Vermicompost (1:1) gave significantly highest plant height (28.08, 47.54 and 51.81 cm) at 30, 60 and 90 DAP, which was followed by (26.58, 44.16 and 48.39 cm) Soil: FYM (1:1), while Soil alone produced the lowest plant height (26.22, 44.00 and 48.12cm) at each observation, i.e., 30, 60, and 90 DAP, respectively.

The interaction of rooting hormones and growing media resulted in significant increase in plant height at 30, 60 and 90 DAP. The maximum plant height (33.03, 54.23 and 57.89 cm) at 30, 60 and 90 DAP was observed in treatment combinations IBA 400 ppm along with Soil: Vermicompost (1:1), which was statistically at par (31.69, 52.23 and 55.53 cm) with NAA 400 ppm with Soil: Vermicompost (1:1) at 30, 60 and 90 DAP, however distilled water along with soil media had the lowest plant height (21.60, 32.87 and 37.73 cm) during the research work.

The interaction between rooting hormones and growing media had a positive effect on plant height. This could be due to the enhancement of protein synthesis, which may have led to increased vegetative growth, as well as increased cell division and cell enlargement attributed to the early and larger number of roots developed in this treatment, which increased water and nutrient absorption and allowed for maximum height through healthy growth associated with the presence of vermicompost in media. It contains both micronutrients and a sustainable source of macronutrients, such as nitrates, phosphates, exchangeable calcium and soluble potassium.

Plant spread (cm)

The plants treated with different rooting hormones had a significant increase in plant spread. The maximum plant spread (15.39, 33.91 and 36.54 cm) at 30, 60 and 90 DAP was noted under IBA 400 ppm (H3), which was found to be statistically at par (14.99, 32.37 and 35.91 cm) with NAA 400

ppm (H5) at 30, 60 and 90 DAP, while the minimum plant spread (8.01, 25.37 and 27.84 cm) was observed under control (H1) at 30, 60 and 90 DAP, respectively. Different growing media showed significant impact on plant spread. Maximum plant spread (13.18, 32.21 and 34.76 cm) at 30, 60 and 90 DAP was observed under Soil: Vermicompost (1:1), which was statistically at par with (12.27, 30.85 and 33.82) at 30, 60 and 90 DAP in Soil: FYM (1:1), while minimum plant spreads (11.41, 29.20 and 32.54 cm) were noted under media Soil at each observation i.e., 30, 60 and 90 DAP, respectively. Enhance metabolic activities of the plants altered the uptake of water and nutrients due to better establishment of roots in media, resulting in significant increase in plant spread. A second factor might be an increase in the plant's lateral growth, which could increase the spread of the plants. Growing media increases adequate aeration, water holding capacity, supplies a significant quantity of nutrients through root absorption, which converts to photosynthesis and aids in cell division. Cell elongation produces a bigger stem diameter.

Survival percentage of rooted cutting (%)

The maximum survival percentages (83.60, 80.87 and 79.05%) were observed in IBA 400 ppm (H3) at 30, 60 and 90 DAP, which was statistically at par (78.38, 75.66 and 73.57%) with IBA 200 ppm (H2), while the lowest survival percentage (49.07, 47.62 and 46.60%) at 30, 60 and 90 DAP, respectively was observed at control (H1). The effect of growing media on survival percentage was found statistically significant among different growing media Soil: Vermicompost (1:1) showed highest survival (75.18, 72.76 and 70.46%) at 30, 60 and 90 DAP, followed by (68.14, 65.86 and 64.57%) at 30, 60 and 90 DAP under Soil, while the lowest survival percent (67.95, 65.73 and 63.96%) at 30, 60 and 90 DAP was observed in Soil: FYM (1:1).

The formation of an efficient root system in terms of number and length of roots, which aided in the uptake of nutrients and water from the soil, could be responsible for the increase in survival percentage of rooted cuttings. Vermicompost's presence in the rooting medium may have enhanced it with plant nutrients (N, P2O5, and K2O), secondary elements (Ca and Mg) and essential micronutrients (Fe, B, Zn and Mo) that play a role in a variety of metabolic processes both directly and indirectly Marigold.

Table 1: Main effect of different rooting hormones and growing media on rooting of marigold.

Treatment combinations	Days to rooting	Rooting success	Root Length (cm)	Fresh weight of root per cutting (g).	Dry weight of root per cutting (g).	Plant height (cm)	Plant spread (cm)	Survival percentage of rooted cutting (%)
Rooting hormones								
H1	13.64	62.38	6.00	0.448	0.035	21.46	8.01	49.07
H2	9.64	86.01	9.42	0.652	0.057	28.74	13.73	78.38
H3	8.88	88.31	8.63	0.747	0.071	30.99	15.39	83.60
H4	12.00	79.54	8.75	0.611	0.044	26.73	13.91	73.92
H5	11.04	82.16	7.54	0.711	0.069	30.63	14.99	75.81
H6	9.73	72.02	7.44	0.573	0.048	25.88	10.01	66.67
H7	9.62	73.44	6.93	0.521	0.050	24.88	9.96	65.51
SEM	0.079	0.559	0.062	0.008	0.001	0.312	0.192	1.657
CD at 5%	0.227	1.6	0.177	0.022	0.002	0.894	0.551	4.747
Growing Media								
M1	10.91	74.77	7.37	0.593	0.052	26.22	11.41	68.14
M2	10.66	77.90	7.86	0.599	0.053	26.58	12.27	67.95
M3	10.38	80.42	8.22	0.635	0.056	28.08	13.18	75.18
SEM	0.052	0.366	0.041	0.005	0	0.204	0.126	1.085
CD at 5%	0.148	1.048	0.116	0.015	0.001	0.586	0.361	3.107

H_1 (distilled water) M_1 (Soil)
H_2 (IBA 200 ppm) M_2 (Soil: FYM 1:1)
H_3 (IBA 400 ppm) M_3 (Soil: Vermicompost 1:1)
H_4 (NAA 200 ppm)
H_5 (NAA 400 ppm)
H_6 (IBA100 ppm + NAA100 ppm)
H_7 (IBA200 ppm + NAA200p ppm)

Table 2: Interaction effect of different rooting hormones and growing media on rooting of marigold.

Treatment combinations	Days to rooting	Rooting success	Root Length (cm)	Fresh weight of root per cutting (g).	Dry weight of root per cutting (g).	Plant height (cm)	Plant spread (cm)	Survival percentage of rooted cutting (%)
H1M1	13.80	60.07	5.56	0.433	0.034	21.60	7.21	47.22
H1M2	13.66	62.07	5.81	0.447	0.035	20.77	7.89	44.44
H1M3	13.46	65.00	6.64	0.463	0.037	22.00	8.94	55.55
H2M1	9.80	83.43	8.19	0.640	0.054	27.13	13.10	72.83
H2M2	9.66	86.17	9.78	0.647	0.057	28.37	13.58	76.53
H2M3	9.46	88.43	10.30	0.670	0.060	22.00	14.52	85.77
H3M1	9.20	85.81	8.18	0.727	0.068	29.01	14.18	78.60
H3M2	9.06	87.20	8.75	0.743	0.070	30.93	15.21	83.33
H3M3	8.40	91.93	8.96	0.770	0.074	33.03	16.79	88.88
H4M1	12.40	77.97	8.34	0.583	0.042	25.90	12.71	70.83
H4M2	11.66	79.17	8.87	0.620	0.045	26.33	14.11	73.35
H4M3	11.93	81.50	9.04	0.630	0.046	27.97	14.92	77.57
H5M1	11.60	80.17	7.32	0.670	0.066	30.90	13.68	72.03

H5M2	11.26	82.97	7.50	0.703	0.069	29.30	15.24	75.60
H5M3	10.26	83.33	7.81	0.760	0.071	31.69	16.06	79.80
H6M1	9.88	67.30	7.30	0.570	0.048	25.30	9.54	68.80
H6M2	9.80	73.27	7.40	0.530	0.044	25.97	9.90	61.11
H6M3	9.53	75.50	7.60	0.620	0.053	26.37	10.58	70.11
H7M1	9.73	68.63	6.71	0.530	0.052	23.67	9.45	66.66
H7M2	9.53	74.47	6.93	0.500	0.048	24.40	9.94	61.26
H7M3	9.60	77.23	7.16	0.533	0.051	24.77	10.48	68.61
SEM	0.137	0.968	0.107	0.013	0.001	0.541	0.333	2.871
CD at 5%	0.393	N/S	0.307	0.039	0.004	1.549	N/S	N/S
CV%	2.221	2.16	2.39	5.19	0	3.48	4.70	7.06

Treatment Combinations

T_1 H1M1 Control (Distilled water + Soil)	T_2 H1M2 (Distilled water + Soil: FYM 1:1)	T_3 H1M3 (Distilled water + Soil: Vermicompost 1:1)
T_4 H2M1 IBA200 ppm + Soil	T_5 H2M2 IBA200 ppm + Soil: FYM 1:1	T_6 H2M3 IBA200 ppm + Soil: Vermicompost 1:1
T_7 H3M1 IBA400 ppm + Soil	T_8 H3M2 IBA400 ppm + Soil: FYM 1:1	T_9 H3M3 IBA400 ppm + Soil: Vermicompost 1:1
T_{10} H4M1 NAA200 ppm + Soil	T_{11} H4M2 NAA200 ppm + Soil: FYM 1:1	T_{12} H4M3 NAA200 ppm + Soil: Vermicompost 1:1
T_{13} H5M1 NAA400 ppm + Soil	T_{14} H5M2 NAA400 ppm + Soil: FYM 1:1	T_{15} H5M3 NAA400 ppm + Soil: Vermicompost 1:1
T_{16} H6 M1 IBA100+NAA100 ppm + Soil	T_{17} H6M2 IBA100+NAA100 ppm + Soil: FYM 1:1	T_{18} H6M3 IBA100+NAA100 ppm + Soil: Vermicompost 1:1
T_{19} H7M1 IBA200+NAA200 ppm + Soil	T_{20} H7M2 IBA200+NAA200 ppm + Soil: FYM 1:1	T_{21} H7M3 IBA200+NAA200 ppm + Soil: Vermicompost 1:1

Conclusion

The following conclusion may be drawn from the results of this study. Among rooting hormones IBA 400 ppm gives significantly better performance at parameters like days to rooting, rooting success, fresh weight of root, dry weight of root. Plant height, plant spread, survival percentage and IBA 200 ppm gives longest root length

In case of growing media Soil: Vermicompost (1:1) out performed in all the parameters of Rooting like days to rooting, rooting success, root length, fresh weight of root, dry weight of root, plant height and plant spread.

In case of interaction of different rooting hormones concentration and growing media, treatment combination IBA 400 ppm along with Soil: Vermicompost (1:1) showed least days to rooting, maximum rooting success, maximum fresh weight of root, highest dry weight of root. maximum plant height, maximum plant spread and highest survival percentage.

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