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IMPACT OF GROWTH REGULATORS ON GROWTH AND YIELD CHARACTERISTICS OF AFRICAN MARIGOLD (*TAGETES ERECTA* L.) CV. PUSA NARANGI GAINDA

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ABSTRACT

The marigold, a member of the Asteraceae family and classified under *Tagetes* spp., is among the most frequently cultivated flowering plants. Plant growth regulators are crucial in flower production, as even small amounts can either enhance, suppress, or alter the growth and development of plants in a measurable way. Hence, the present investigation was conducted at Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Division of Horticulture, during 2020-21 and 2021-22 to standardize the commercial application of growth regulators for getting higher productivity. Two levels of spraying (25 and 45 days after transplanting) were used in the course of the research arranged using a factorial randomized block layout with three replications applied to the African marigold variety Pusa Narangi Gainda. The results revealed that treatment G_2 (GA_3 150 ppm) was the finest in increment in plant height, plant spread, leaf width, leaf length, leaf area, number of primary branches per plant, number of flowers per plot and flower yield. Hence, it might be concluded that the application of growth regulator GA_3 150 ppm can be helpful and recommended in improving growth and yield characteristics in commercial cultivation of marigold.

Key words : Ethrel, Gibberellic acid, Growth regulators, Marigold, Growth, Yield.

Introduction

Commercial floriculture has attracted attention in India due to enormous export potential and increased domestic utilization of flowers in daily life with the upgrade in living standards of people. Marigold (*Tagetes erecta* L.) is a significant commercial flower in India, which is highly favored for its ease of cultivation and broad adaptability, making it a popular choice among growers (Ravneet *et al*., 2012). Marigolds belong to the genus *Tagetes* within the Asteraceae family and are native to Central and South America, particularly Mexico. The genus name *Tagetes* is derived from *Tages*, a revered deity from ancient Egypt known for his exquisite beauty. There are approximately 33 species in this genus, with three *Tagetes erecta* (African marigold), *Tagetes patula* (French marigold) and *Tagetes tenuifolia* (Striped marigold) being the most widely cultivated (Singh and Sisodia, 2018). In India, African marigold flowers are commonly sold loose in markets for crafting garlands. These flowers are traditionally utilized in religious ceremonies at temples and churches, as well as during festivals to enhance the visual appeal of landscapes (Tomar *et al*., 2004). The flowers are highly valued for their hardiness, ease of cultivation, adaptability to various soil and weather conditions, and convenience in transportation, which makes them particularly appealing to flower growers (Kumar and Sharma, 2013). Nowadays flowers of African marigold are gaining significant industrial importance due to their vast potential in value addition. To meet the growing demand from industrialists, it is essential to enhance its production through advanced cultivation techniques (Tyagi *et al*., 2006). The use of growth regulators can play a crucial role in boosting production levels. Plant growth regulators have become widely recognized for their role in enhancing plant yield by influencing growth patterns, developmental processes, and stress responses (Tripathi *et al*., 2003). Gibberellic acid (GA_3) has been shown to significantly improve plant growth and enhance flower production in marigold (Girwani *et al*., 1990) and also influences plant development by promoting both cell division and cell expansion (Sunitha, 2007). Gibberellic acid has proven to be highly effective in regulating the growth and promoting flowering in marigolds (Kumar and Sharma, 2013). Conversely, Ethrel is known to suppress plant height, reduce the number of nodes and internodal lengths, encourage branching and delay the onset of flowering (Varma and Arha, 2004). Hence, the present investigation was carried out to access the effect of growth regulators on growth and yield characteristics of African marigold and standardize the dose of growth regulators for making recommendations to the farmers for their optimal and economical uses.

Materials and Methods

The current study was carried out in the Division of Horticulture, Rajasthan Agricultural Research Institute, located in Durgapura, Jaipur during October to January seasons of 2020-21 and 2021-22, respectively. The research study comprised two levels of spraying (25 and 45 days after transplanting). It was set up in a factorial randomized block design with three replications. The 120 × 60 × 10 cm raised beds were used to spread the marigold seeds. The seedlings, which were put in lines with a 40 × 40 cm spacing, were 30 days old, uniform in height, robust, and strong with 5–6 leaves. According to the treatment, spraying was done once at 35 days after transplanting and 65 days after transplanting. The GA_3 (Gibberellic acid technical) was applied in the powder form (GA_3 90% w/w and Adjuvants 10% w/w), NAA (Planofix) was applied in liquid forma (100% ai, 4.50% w/w Adjuvants, Q.S. to make 100% w/w), Ethrel was also applied in liquid form (Ethephon 39 % S.L.). Five randomly chosen and labelled plants per plot were used to collect the data related to plant growth and yield traits. In order to evaluate the importance of variance in data derived from different growth, yield and quality characteristics, the Fisher (1950) factorial randomized block design technique was utilized to apply analysis of variance. The statistical analysis was done using the opstat software package (Sheron *et al*., 1998).

Results and Discussion

Impact of growth regulators on plant growth characteristics

The results collected from the present experimental design regarding plant vegetative growth characteristics is displayed in Table 1, which clearly demonstrated that the appositeness of growth regulators in different combinations had produced pronounced effect on growth attributes of marigold flower. The maximum plant height was acquired in treatment G_2 (GA_3 150 ppm) (65.6 cm and 68.2 cm) and merest was observed in G_6 (Ethrel 700 ppm) (51.0 cm and 54.3 cm) in 2020-21, 2021-22 and pooled data respectively. There was an increase of 27.18 % in plant height in treatment G_2 as compared to G_6. The remarkable plant height observed in the treatment G_2 (GA_3 150 ppm) was mostly caused by the activity of gibberellins which promote abundant growth by cell division and cell elongation and this may have emanated in the increase of plant height. However, the plant height is a genetically controlled aspect; it is evident from results that, GA_3 has played a compelling role in increasing the plant height (Issac *et al*., 2009). The plant spread (42.3, 45.4 and 43.9 cm) was recorded maximum with application of treatment G_2 (GA_3 150 ppm) and minimum in the treatment G_6 (Ethrel 700 ppm) (33.8, 36.2 and 35.0 cm) correspondingly for the years 2020-21, 2021-22 and with pooled mean. There was an increase of 25.42 % in plant spread in treatment G_2 (GA_3 150 ppm) as compared to G_6 (Ethrel 700 ppm). Plant spread due to GA_3 150 ppm is likely increased due to enhanced metabolic activity and changes in water and nutrient uptake, which were influenced by this concentration of GA_3 (Kadam *et al*., 2002). The highest number of primary branches was observed in treatment G_2 (GA_3 150 ppm) (13.98, 16.30 and 15.14) and lowest number of primary branches was observed in G_6 (Ethrel 700 ppm) (11.68, 14.20 and 12.94) in 2020-21, 2021-22 and pooled data respectively. The application of G_2 (GA_3 150 ppm) recorded the significantly greatest number of primary branches per plant over G_6 (Ethrel 700 ppm) treatment respectively to the ballad of (17.00%) pooled mean. This significant expansion in number of branches per plant might be because of spare vegetative growth especially height of the plant due to pertinence of GA_3 in optimum dose (150 ppm) thus resulting in promotion of lateral branches (Sanap *et al*., 2004). The maximum leaf length (11.1, 12.0 and 11.5 cm), width (6.67, 7.26 and 5.25 cm) and leaf area (46.5, 47.5, 49.8 cm^2) was captured in treatment G_2 (GA_3 150

Table 1 : Impact of growth regulators on plant growth and yield characteristics of African marigold.

Treatments	Plant height (cm)			Plant spread (cm)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
G_1-GA_3 75 ppm	64.0	67.5	65.7	41.7	44.7	43.2
G_2-GA_3 150 ppm	65.6	68.2	66.9	42.3	45.4	43.9
G_3-NAA 25 ppm	54.0	57.3	55.6	39.4	42.5	40.9
G_4-NAA 50 ppm	63.6	67.7	65.6	41.5	44.6	43.0
G_5-Ethrel 450 ppm	56.9	60.3	58.6	37.4	40.0	38.7
G_6-Ethrel 700 ppm	51.0	54.3	52.6	33.8	36.2	35.0
SEm$\pm$	1.08	1.14	0.55	0.60	0.64	0.30
CD (P=0.05)	3.04	3.22	1.53	1.68	1.81	0.85
Treatments	**Number of primary branches per plant**			**Leaf length (cm)**		
G_1-GA_3 75 ppm	12.68	15.60	14.14	11.0	11.9	11.4
G_2-GA_3 150 ppm	13.98	16.30	15.14	11.1	12.0	11.5
G_3-NAA 25 ppm	10.28	13.50	11.89	10.6	10.5	10.5
G_4-NAA 50 ppm	13.28	16.00	14.64	10.8	11.8	11.3
G_5-Ethrel 450 ppm	12.48	15.10	13.79	11.0	11.1	11.0
G_6-Ethrel 700 ppm	11.68	14.20	12.94	9.7	10.1	9.9
SEm$\pm$	1.08	1.14	0.53	0.17	0.19	0.09
CD (P=0.05)	3.04	3.22	1.49	0.47	0.54	0.25
Treatments	**Leaf width (cm)**			**Leaf area (cm^2)**		
G_1-GA_3 75 ppm	6.62	7.24	6.93	45.9	47.0	46.4
G_2-GA_3 150 ppm	6.67	7.26	6.96	46.5	47.5	47.0
G_3-NAA 25 ppm	4.60	6.50	5.55	44.3	45.0	44.6
G_4-NAA 50 ppm	6.60	7.21	6.90	45.7	46.8	46.3
G_5-Ethrel 450 ppm	5.60	7.00	6.30	43.0	43.2	43.1
G_6-Ethrel 700 ppm	4.30	6.20	5.25	41.2	41.4	41.3
SEm$\pm$	0.05	0.07	0.03	0.55	0.64	0.27
CD (P=0.05)	0.13	0.19	0.08	1.55	1.80	0.77
Treatments	**Plant fresh weight (g)**			**Plant dry weight (g)**		
G_1-GA_3 75 ppm	276.08	277.71	276.89	83.03	87.11	85.07
G_2-GA_3 150 ppm	279.73	283.15	281.44	84.63	88.91	86.77
G_3-NAA 25 ppm	238.65	238.51	238.58	67.53	69.40	68.47
G_4-NAA 50 ppm	274.48	276.15	275.31	82.83	86.96	84.89
G_5-Ethrel 450 ppm	208.59	207.51	208.05	65.73	67.10	66.42
G_6-Ethrel 700 ppm	187.68	191.71	189.69	50.63	53.40	52.02
SEm$\pm$	3.96	3.96	2.24	1.24	1.25	0.77
CD (P=0.05)	11.18	11.18	6.26	3.50	3.52	2.15
Treatments	**Plant total biomass (q/ha)**			**Plant root-shoot ratio**		
G_1-GA_3 75 ppm	65.08	66.70	65.89	0.177	0.183	0.180
G_2-GA_3 150 ppm	66.58	67.50	67.04	0.187	0.194	0.191
G_3-NAA 25 ppm	59.78	68.00	63.89	0.166	0.169	0.167
G_4-NAA 50 ppm	64.73	65.95	65.34	0.168	0.177	0.173
G_5-Ethrel 450 ppm	56.08	59.20	57.64	0.152	0.160	0.156
G_6-Ethrel 700 ppm	52.56	54.20	53.38	0.137	0.143	0.140
SEm$\pm$	1.24	1.25	0.64	0.020	0.020	0.010
CD (P=0.05)	3.50	3.52	1.80	0.057	0.057	0.028

Table 1 continued...

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Treatments	Number of flowers per plot			Flower yield (q/ha)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
G_1-GA_3 75 ppm	797.0	804.0	800.0	169.20	171.77	170.48
G_2-GA_3 150 ppm	804.0	824.0	814.0	171.27	174.70	172.98
G_3-NAA 25 ppm	701.0	713.0	707.0	153.42	155.58	154.50
G_4-NAA 50 ppm	778.0	797.0	788.0	166.64	171.27	168.95
G_5-Ethrel 450 ppm	614.0	661.0	637.0	132.87	135.54	134.21
G_6-Ethrel 700 ppm	577.0	614.0	595.0	131.94	126.63	129.29
SEm$\pm$	6.95	7.61	3.74	3.43	3.43	1.77
CD (P=0.05)	19.60	21.48	10.40	9.67	9.67	4.95

ppm) whereas minimum mean leaf length (9.7, 10.1 and 9.9 cm), width (4.30, 6.20 and 5.25 cm) and leaf area (41.2, 41.4 and 39.7 cm^2) were found in treatment G_6 (Ethrel 700 ppm) for the year 2020-21, 2021-22 and pooled data, respectively. There was an increase of 16.16% in leaf length, 32.57% in width and 13.80 % in leaf area in treatment G_2 (GA_3 150 ppm) as compared to G_6 (Ethrel 700 ppm). GA_3 promotes increased leaf length and width by activating enzymes that weaken cell walls, allowing for cell elongation. It stimulates starch hydrolysis, leading to higher sugar concentrations, which raises osmotic pressure in the cell. This increased pressure draws water into the cells, causing them to expand (Kumar and Sharma, 2013). The gain in plant leaf area with application of GA_3 seems to be due to amplify cell division and cell enlargement, promotion of protein synthesis coupled with greater dry matter accumulation in the plant (Rana *et al*., 2005). The highest mean plant fresh weight (279.73, 283.15 and 281.44 g) was observed in treatment G_2 (GA_3 150 ppm), whereas lowest fresh weight (187.68, 191.71 and 189.69 g) was seen in treatment G_6 (Ethrel 700 ppm) in year 2020-21, 2021-22 and pooled data respectively. This might be because GA_3 adequacy stimulate cell elongation is that the hydrolysis of starch ensuing from the production of GA_3 induced amylase which might escalate the concentration of sugars, resulting in higher plant spread, more number of branches enlarge leaf length, width and area which ultimately caused augment plant weight as compared to other treatments (Chandrappa *et al*., 2006). The highest dry weight (84.63, 88.91 and 86.77 g) was seen in G_2 (GA_3 150 ppm) in case of lowest dry weight (50.63, 53.40 and 52.02 g) was found in treatment G_6 (Ethrel 700 ppm) in the year 2020-21, 2021-22 and pooled data, respectively. The maximum plant biomass (66.58, 67.50 and 67.04 q/ha) and plant root-shoot ratio (0.187, 0.194 and 0.222) was found in G_2 (GA_3 150 ppm) and minimum plant biomass (52.56, 54.20 and 53.38 q/ ha) and plant root-shoot ratio (0.137, 0.143 and 0.126) was seen in treatment G_6 (Ethrel 700 ppm) in year 2020-21, 2021-22 and pooled data, respectively. The increase in percentage plant root-shoot ratio under treatment G_2 (GA_3 150 ppm) was found to be (36.42 %) more over treatment G_6 (Ethrel 700 ppm). The increase in percentage plant dry weight under treatment G_2 (GA_3 150 ppm) was found to be (66.80%) more over treatment G_6 (Ethrel 700 ppm). The increment in dry weight of plant was due to overall promotion and luxurious arable growth. So, increase in biomass accumulation and plant root-shoot ratio in response to GA_3 application and it emulated on increase in dry weight of plant (Sinha, 2004). These results are in configuration with that reported by Girish *et al*. (2012), Sudhakar and Ramesh (2012), Ahmed *et al*. (2013), Girisha *et al*. (2013), Kumar *et al*. (2014), Sasikumar *et al*. (2015), Sathappan (2018) and Mujadidi *et al*. (2019).

Impact of growth regulators on yield characteristics

The results obtained from the current experiment regarding the yield attributes is displayed in Table 1, which clearly indicated the impact of growth regulators in producing pronounced effect on yield attributes of marigold flower. The highest mean number of flowers per plot (804.0, 824.0 and 814.0) was seen in G_2 (GA_3 150 ppm) while lowest number of flowers per plot (577.0, 614.0 and 595.0) was observed in G_6 (Ethrel 700 ppm). Application of G_2 (GA_3 150 ppm) significantly build up the number of flowers per plot increase to the extent of 36.80% in pooled mean over treatment G_6 (Ethrel 700 ppm). The greater weight of flowers per plot in foliar application of G_2 (GA_3 150 ppm) plants can be due to the accumulation of assimilates resulting in adequate food reserves. This escalation in number of flowers per plot under G_2 (GA_3 150 ppm) over the other treatments can be attributed to the fact that GA_3 treated plants stayed physiologically more active to build up acceptable food stocks, which in turn, promoted exceeding plant growth and ultimately extra number of flowers, leading to more yields (Badge *et al*., 2015). The mean maximal flower yield per hectare (171.27, 174.70 and 172.98 q/ha) was obtained in treatment G_2 (GA_3 150 ppm) and minimal mean flower yield per hectare (131.94, 126.63 and 129.38 q/ha) was found in treatment G_6 (Ethrel 700 ppm) in year 2020-21, 2021-22 and pooled mean respectively. Treatment G_2 (GA3 150 ppm) registered (33.74 %) increases in flower yield over treatment G_6 (Ethrel 700 ppm). The presence of GA_3 have increased the growth elevate enzymes there by synthesizing nucleic acid in the plants. Since RNA and DNA synthesis are mostly higher nuclear and centralized in chloroplasts which potency have accelerated the rate of food assimilation and ultimately efficacy have increased the sum of flowers as well as the yield per plant (Kumar *et al.*, 2014). Ethylene mainly works in optimum dose escalating the cell permeability and flower comes to good blooming. High dose ethylene gives negative effect of yield attributes because ethylene induction of epinasty (leaf bending), leaf abscission, stem swelling, inhibition of stem and root growth and flower petal discoloration (Ramesh *et al*., 2013). Similar results were also described by Ismaeil and Youssef (2008), Mayoli *et al.* (2009), Saraswathi and Vadivel (2009), Kumar *et al.* (2012), Khobragade *et al.* (2014), Badge *et al.* (2015) and Rajhansa *et al.* (2015).

Conclusion

From the present investigation, the final results revealed that the treatment G_2 (GA_3 150 ppm) was discovered to be ideal for increasing plant height, plant spread, number of primary branches per plant, leaf length, leaf width, leaf area, plant fresh weight, plant dry weight (g), total biomass (q/ha), root-shoot ratio, number of flowers per plot and flower yield per hectare. Whereas treatment G_6 (Ethrel 700 ppm) showed minimal result for all the above-mentioned characters. Therefore, it might be concluded and can be recommended to the farmers growing African marigold crop, that the application of growth regulator Gibberllic acid (GA_3) 150 ppm at 35 DAT and 65 DAT can be helpful in enhancing growth as well as yield characteristics in commercial cultivation of African marigold.

Future scope

As the present research identified GA_3 150 ppm at 35 DAT and 65 DAT helpful in enhancing growth as well as yield characteristics in marigold crop. Further research can be done with the marigold cultivation using GA_3 and other growth regulators. This would be to optimize concentrations of GA_3 and PGR's with different varieties for quality after harvesting and enhanced tolerance towards environmental stresses. More important aspects of future research may include study into the molecular mechanisms underlying the effect of GA_3 and other economic analyses on commercial usage. Further commercial exploitation and sustainability in marigold cultivation can be achieved by replicating the studies across different agro climatic regions, integrating GA_3 with organic enhancers, and studying its effect on other species of *Tagetes*, such as French marigold.

Conflict of interest : Authors have declared that no competing interests exist.

Author contributions : Kanheya Lal Yadav conceived and designed the analysis, collected the data and performed the data analysis, Ram Swaroop Meena conceived and designed the analysis, B.R. Vasavi wrote the paper, Udit Joshi wrote the paper and Kamlesh Kumar Yadav performed the data analysis and edited the paper.

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