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Effect of Plant Growth Regulators on Quality Attributes of Growth, Development and Yield of African Marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda

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ABSTRACT

Background: African Marigold *Tagete serecta* L., is widely cultivated for both as cut and loose flower production in different parts of India. Marigolds are colourful, adaptable herbaceous annuals known for their large, colourful solitary blooms. The experiment was conducted to study the effect of different plant growth regulators and retardants on the growth and development of African marigold.

Methods: The experiment was laid out inRandomized Block Design, consisting 13 (thirteen) treatments *i.e.*, T_1- Control (Distilled water spray), T_2- NAA@ 75 ppm, T_3-NAA@ 125 ppm, T_4-NAA@ 175 ppm, T_5-GA_3@ 100 ppm, T_6-GA_3@ 150 ppm, T_7-GA_3 @ 200 ppm, T_8- ALAR @ 400 ppm, T_9- ALAR @ 600 ppm, T_{10}- ALAR @ 800 ppm, T_{11}- MH @ 300 ppm, T_{12}- MH @ 500 ppm, T_{13}- MH @ 700 ppm.

Result: The result showed statically significant difference among the treatments. The plants when treated with GA_3 @ 150 ppm gave the highest plant height (81.17 cm), number of leaves per plant (315.08), stalk length (41.67 cm), number of flowers per plant (69.83), number of flowers per bed (1396.67), minimum days for first flower bud initiation (40.50 days), first flower bud opening (4.67 days) where as maximum days for first flower wilting (12.43 days), maximum duration of flowering (40.67 days) per plant.

Key words: African marigold, Growth regulators, Quality attributes.

INTRODUCTION

Marigold is one of the commercially exploited flower crop and is native to North America (Jadhav, 2018; Narute *et al*., 2020) belongs to the class Magnoliopsidae and family Asteraceae / Compositae (Shafiullah *et al*., 2018; Singh *et al*., 2018; Pradhan and Maitra, 2020) and has ornamental, pharmaceutical, ceremonial and antimicrobial properties (Gómez-Rodríguez *et al*., 2003) besides its use in landscape gardening (Shivaprakash *et al.*., 2011). The generic name *Tagetes* is derived from the Greek demigod Tages, renowned for his beauty. Thegenus *Tagete s*contains about 33 species (Rydeberg, 1915). The species (African Marigold) *Tagete serecta,* is widely cultivated for both as cut and loose flower production in different parts of India. There are numerous instances in which plant growth hormones are used to control flowering in various plants. Gibberellic acid (GA_3) and Naphthalene Acetic Acid (NAA) are essential for enhancing the vegetative growth characteristics of plants because they stimulate cell division and elongation bye ncouraging the production of Deoxyribonucleic acid (DNA) inthecell (Murugan *et al.,* 2020). Depending on the variety cultivated, the response to these practices can differ. In order to optimize the yield of plants by modifying growth, development and stress behavior, plant growth regulators have gained broad acceptance (Shukla and Farooqi, 1990). Mujadidi *et al*. (2019) did an experiment on African Marigold for growth and flowering they revealed that GA_3 application at 300 ppm (40 DAT) led to the longest plant height, maximum plant spread and maximum branch number.

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African Marigold found effective in respect of plant height, number of branches, leaf area, flower diameter, flower weight and yield with GA_3 @ 150 ppm (Reddy, 2018) and GA_3 @ 200 ppm (Kousika *et al*., 2021). Murugan *et al*. (2020) found that NAA treatment maximized flower yield and xanthophyll content in African Marigold, with increased flower weight and flower number. Swaroop *et al*., (2007) found Application of NAA at 300 ppm to African Marigold cv. Pusa Narangi Gainda increased single flower weight, number of flowers per plant and flower yield per plant. Maleic hydrazide (MH) and Alar are the growth retardants are being used for producing quality flowers and seeds (Murugan *et al*., 2020; Shanmugam *et al*., 1973). Hence, in this present study, two growth regulators namely (NAAandGA_3) and two growth retardant snamely (Maleic hydrazide and Alar) have been applied as foliar spray in different concentration to assess the response of AfricanMarigold for growth and development as well as seed yield.

MATERIALS AND METHODS

This experiment was carried out at the Instructional Farm, Department of Floriculture, Medicinal and Aromatic Plants, Faculty of Horticulture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal India during 2021-2022 from October 2021 to March 2022.The treatment employed in the experiment were T_1- Control (Distilled water spray), T_2- NAA@ 75 ppm, T_3- NAA@ 125 ppm, T_4- NAA@ 175 ppm, T_5- GA3 @ 100 ppm, T_6- GA3 @ 150 ppm, T_7- GA3 @ 200 ppm, T_8- ALAR@ 400 ppm, T_9- ALAR@ 600 ppm, T_{10}- ALAR@ 800 ppm, T_{11}- MH@ 300 ppm, T_{12}- MH@ 500 ppm, T_{13}- MH@ 700 ppm. The treatments was laid out in a randomized complete block design (RCBD), resulting in a total of 13 treatment combinations with 3 replications. The seeds of African marigold cv Pusa Narangi Gainda were collected from division of Floriculture and Landscaping, IARI, Pusa, New Delhi.

The experimental area was ploughed twice with the help of tractor-drawn implements in both directions and harrowing was done to break the clods followed by levelling. Stones, pebbles and plant residues were removed manually from the field. The field was levelled to provide appropriate water drainage. The layout of raised beds of the required size (2 m×1.2 m) was done with rope and properly leveled beds were prepared with a spacing of (40 cm×30 cm). FYM @ of 20 tonnes per hectare was applied at the time of bed preparation as a basal dose. NPK@ 120: 100: 100 kg per hectare were applied in the soil.

The stock solution of GA_3 was prepared by dissolving 100 mg of GA_3 ina small quantity of ethyl alcohol (C_2H_5OH). The distilled water was added in the solution to make up the total volume up to 1000 ml resulting in to 100 ppm stock solution. Similarly, 150 ppm and 200 ppm stock solutions of GA3 were also prepared in this way (Singh *et al.,* 2018; Patil *et al.,* 2016).

The stock solution of NAA was prepared by dissolving 75 mg of NAA in a small quantity of Ammonium Hydroxide (NH_4OH). The distilled water was added in the solution to make the total volume up to 1000 ml resulting into 75 ppm stock solution. Similarly, 125 ppm and 175 ppm stock solutions of NAA were also prepared (Singh *et al*., 2018).

The stock solution of MH was prepared by dissolving 300 mg of MH in small quantities of ethyl alcohol (C_2H_5OH). The distilled water was added in the solution to make the total volume up to 1000 ml resulting in to 300 ppm stock solution. Same as the above result 500 ppm and 700 ppm stock solutions were also prepared.

The stock solution of Alar was prepared by dissolving 400 mg of Alar in a small quantity of ethylalcohol (C_2H_5OH). The distilled water was added to the solution to make the total volume to 1000 ml, resulting in a 400 ppm stock solution. Same as the above result other stock was also prepared.

All the prepared stock solutions were applied to the plants as foliar application through a hand sprayer. The spraying was done two times separately on each plot of treatments *viz*. 20 days after transplanting and 40 days after transplanting. NPK- Nitrogen (urea), phosphate (SSP) and potassium (MOP) were applied @120:100:100 kg per hectare.

The experiment was designed in a randomized complete block design (RCBD). To collect data on all the vegetative and flowering parameters five randomly selected plants from each replication of each treatment of the experimental plot were tagged. The statistical analysis of data was done by adopting the OP STAT.

RESULTS AND DISCUSSION

Vegetative parameters

An exploratory experiment involving thirteen treatments of GA_3, NAA, MH and Alar showed significant differences in plant height. The spraying of GA_3 @150 ppm resulted in maximum height (81.70 cm) and MH@ 700 ppm applied resulted in minimum height (of 54.43 cm). The number of leaves was found maximum (315.08) inplant sreceived with GA_3@ 150, while a minimum number of leaves per plant (207.58) was recorded in control (distilled water spray) (Table 1). The increase in plant height and number of leaves might be due to application of GA_3 which helps in sub-apical meristem cells to grow longer, which had an impact on stem elongation (Reddy, 2018). This may be also because of application of GA_3 which increases the amount of auxin in tissues and improves the conversion of tryptophan to IAA, which leads to cell division and cellelongation (Abel and Theologis, 1996). MH application reduces plant height by inhibiting cell division and elongation in meristem tissues, dwarfing growth and suppressing apical dominance, as reported in African marigold and (Kumar *et al.*, 2020). The maximum plant spread in both directions E-W (60.90 cm) and N-S (63.23 cm) was found maximum in plants when sprayed with GA_3@ 100 ppm and GA_3@ 150 respectively, whereas minimum plant spread in both directions E-W (47.50 cm) and N-S (49.13 cm) was found in plants sprayed with MH @ 700 ppm (Table 1). It might be due to application of which interacting withauxin, reducesapical dominance, which leads to increased plants pread. This interaction mayac count for the increase in plants pread brought on by GA_3 application. Similar findings reported by Reddy (2018) and Mujadidi *et al.* (2019) in African marigold. Maximum number of branches per plant (34.92) was found highest in plant treated with Alar @ 600 ppm

Minimum number of branches per plant (23.08) was found in plants sprayed with control (distilled water spray) (Table 1). Similar findings were reported by Murugan *et al.,* (2020) in African Marigold.

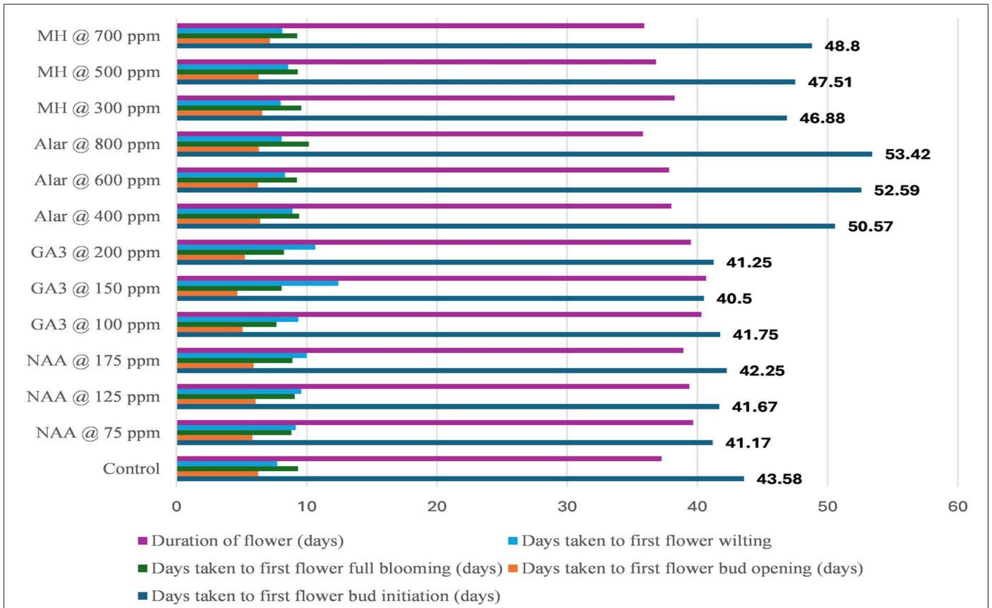
Phenological parameters

The plants sprayed with GA_3@150 ppm took minimum (40.50) days required for initiation of first flowerbud from date of trans planting whereas, plants treated with Alar @800 ppm took maximum days (53.42) days (Fig 1). The findings are in comparable with Kalamani *et al.* (2017) in African Marigold, Prakash *et al.* (2015) in chrysanthemum, Kumar *et al.* (2020) in marigold. Application of GA_3@ 150 ppm took fewer days (4.67) (Fig 1) days for thefirst opening of the first initiated flower bud while MH @ 700 ppm took maximum (7.17) (Fig 1) days for the opening of the first flower bud.As it is clearly revealed that plant received with GA_3@ 150 ppm took least number (7.67) of days for first

Table 1: Effect of plant growth regulators on vegetative attributes.

Treatments	Plant height (cm)	Plant spread (cm) E-W	Plant spread (cm) N-S	Number of leaves per plant	Number of branchesper plants
T_1- Control (distilled water)	66.50	49.75	49.93	207.58	23.08
T_2- NAA @ 75 ppm	69.28	54.03	53.32	289.75	25.42
T_3- NAA @ 125 ppm	69.38	50.98	58.86	246.75	26.08
T_4- NAA @ 175 ppm	72.17	53.08	53.60	264.58	26.50
T_5- GA3 @ 100 ppm	74.33	60.90	61.19	304.17	27.00
T_6- GA3 @ 150 ppm	81.17	60.72	63.23	318.08	28.33
T_7- GA3 @ 200 ppm	76.62	60.22	61.76	315.08	28.33
T_8- Alar @ 400 ppm	63.43	54.50	54.46	262.92	31.50
T_9- Alar @ 600 ppm	61.10	50.33	55.18	269.50	34.92
T_{10}- Alar @ 800 ppm	60.14	53.67	58.82	259.17	31.67
T_{11}- MH @ 300 ppm	59.75	51.83	49.93	239.33	29.50
T_{12}- MH @ 500 ppm	57.25	50.17	53.67	240.83	30.08
T_{13}- MH @ 700 ppm	54.43	47.50	49.13	262.00	31.08
SE(m)±	1.25	1.65	1.37	24.12	0.75
C.D. at 5%	3.68	4.82	4.01	8.22	2.21
C.V. (%)	3.26	5.33	4.27	5.32	4.53

NAA- Naphthalene acetic acid, GA_3- Gibberellic acid, MH- Maleic hydrazide.



NAA- Naphthalene acetic acid,GA_3- Gibberellic acid, MH- Maleic hydrazide.

Fig 1: Graphical presentation of phenological parameters of african marigold.

flower full blooming. More number of days (10.17) days was found in plants when sprayed with Alar@ 800 ppm for full blomming of flowers. Findings were incorroborate with Pal *et al.* (2021) in African Marigold cv. Pusa Narangi Gainda, Dutta *et al.* (1993) and Mujadidi *et al.* (2019) in African Marigold. GA_3@ 150 ppm took highest (12.43) days for first flower wilting whereas, least number (7.73) of days required for first flower wilting was found in control plots. The duration of flowering was found maximum (40.67) days with plants sprayed with GA_3@ 150 ppm. Above results are in similar findings with Pal *et al.* (2021) in African Marigold cv. Pusa Narangi Gainda, Kumar *et al.* (2020) in marigold. Earliness in first flower bud initiation, first flower full opening as well as duration of flowering was found in plants sprayed with GA_3@ 150 ppm (T6) (Fig 1). Gibberellins increase cell division and elongation capacity, shortening juvenile phase and causing early maturity in crop plants. They also initiate early flowering and flower initiation (Phengphachanh *et al.,* 2012).

Table 2: Effec tof plant growth regulators on floral attributes.

Treatments	Flower diameter (cm)	Stalk Length	Total number of flowers	Total number of flowers per plant	Fresh weight of 10 flowers per plot (g)
T_1- Control	6.08	35.12	60.92	1218.33	45.91
T_2- NAA @ 75 ppm	6.97	35.67	62.50	1250.00	47.66
T_3- NAA @ 125 ppm	6.82	36.83	62.92	1258.33	48.57
T_4- NAA @ 175 ppm	6.67	37.93	64.83	1296.67	57.93
T_5- GA3 @ 100 ppm	7.28	40.55	64.08	1281.67	58.91
T_6- GA3 @ 150 ppm	7.02	41.61	69.83	1396.67	62.91
T_7- GA3 @ 200 ppm	7.00	39.36	65.25	1305.00	60.19
T_8- Alar @ 400 ppm	6.61	31.99	61.42	1228.33	56.61
T_9- Alar @ 600 ppm	6.49	33.10	62.08	1241.67	54.54
T_{10}- Alar @ 800 ppm	6.44	31.05	62.17	1243.33	51.85
T_{11}- MH @ 300 ppm	6.23	29.56	58.67	1173.33	46.41
T_{12}- MH @ 500 ppm	6.12	29.03	58.01	1160.20	48.60
T_{13}- MH @ 700 ppm	5.83	27.38	57.17	1143.40	49.00
SE(m)±	0.12	0.43	1.05	21.03	2.98
C.D. at 5%	0.35	1.27	3.08	61.76	8.74
C.V. (%)	3.24	2.17	2.92	2.92	9.72

NAA- Naphthalene acetic acid, GA_3- Gibberellic acid, MH- Maleic hydrazide.

Table 3: Effect of plant growth regulators on seed attributes.

Treatments	Total number of chaffy seeds per head	Total number of healthy seeds per head	Total numbers of seeds per head	Weight of total healthy seeds per head (g)	1000 seed weight (g)	Total seed yield per plant (g)
T_1- Control	187.10	110.68	297.78	0.27	2.40	16.20
T_2- NAA @ 75 ppm	127.00	161.43	288.43	0.41	3.17	25.52
T_3- NAA @ 125 ppm	202.30	164.00	366.30	0.62	3.50	39.01
T_4- NAA @ 175 ppm	181.10	162.33	343.43	0.71	3.63	46.00
T_5- GA3 @ 100 ppm	186.17	176.63	362.80	0.64	3.93	41.51
T_6- GA3 @ 150 ppm	180.23	185.33	365.57	0.81	4.31	56.59
T_7- GA3 @ 200 ppm	176.67	164.23	340.91	0.77	4.17	50.03
T_8- Alar @ 400 ppm	140.17	193.20	333.37	0.60	3.83	36.39
T_9- Alar @ 600 ppm	153.40	197.47	350.87	0.76	3.87	47.28
T_{10}- Alar @ 800 ppm	206.60	188.20	394.80	0.61	3.65	38.04
T_{11}- MH @ 300 ppm	160.50	134.21	294.71	0.53	3.63	30.86
T_{12}- MH @ 500 ppm	211.83	155.80	367.63	0.53	3.25	30.70
T_{13}- MH @ 700 ppm	142.00	127.57	269.57	0.48	3.22	27.64
SE(m)±	16.51	15.87	24.41	0.08	0.30	5.31
C.D. at 5%	48.49	46.59	71.66	0.23	0.87	15.60
C.V. (%)	16.49	16.84	12.56	22.95	14.25	24.63

NAA- Naphthalene acetic acid, GA_3- Gibberellic acid, MH- Maleic hydrazide.

Flowering parameters

Application of GA_3@ 150 ppm produced the highest flower diameter (7.28 cm) and fresh weight of 10 flowers (62.91 g) while minimum weight of 10 fresh flowers (45.91 g.) (Table 2). Above findings are in corroborate with Reddy (2018) in African Marigold, Pal *et al.,* (2021)in African Marigold cv. Pusa Narangi Gainda. Plants sprayed with GA_3@ 150 ppm gave highest stalk length of flower (41.61 cm) (Table 2), Gibberellins induce cell division and elongation, leading to longer flower stalks. Maleic hydrazide inhibits cell division and elongation, causing decreased stalks. These antagonists disrupt plant growth, nullify apical dominance and disrupt carbohydrate and mineral metabolism. (Crafts *et al.*, 1950) Maximum number of flowers per plant (69.83) and flower per plot (1396.67) was found in plants sprayed with GA_3@ 150 ppm (Table 2). Above results are in conformity with Pal *et al.,* (2021) in African Marigold cv. Pusa Narangi Gainda, Reddy (2018) in African Marigold, Kalamani*et al.,*(2017) inAfrican Marigold. The increase in flowers per plant and plot may be attributed to increased vegetative growth, early flower initiation, longer flowering duration, sufficient lateral development, improved reproductive efficiency and a photosynthesis-restrictive plant type in African marigold (Sunitha *et al.*, 2007).

Seed parameters

Different seed yield parameters were significantly influenced by application of plant growth regulators. It was found that minimum number of chaffy seed sperhead (127.00) was found from the plots sprayed with NAA @ 75 ppm, while highest chaffy seeds per head (211.83) was recorded in MH @ 500 ppm (Table 3). Maximum number of healthy seed sperhead (197.47) was registered from plants sprayed with ALAR @ 600 ppm minimum healthy seeds per head (110.68) were resulted from plants sprayed with distilled water (control). Application of GA_3@150 ppm registered highest total seeds per head (365.57) (Table 3). minimumnum berof total seed sperhead (269.57) was resulted from plants sprayed with MH@ 700 ppm (Table 3). Weight of healthy seeds per head (0.81 g) and 1000 seed weight (4.31 g.) were found maximum in plots sprayed with GA_3@ 150 ppm whereas, minimum weight of healthy seeds per head (0.27 g) and lowest 1000 seed weight (2.40 g.) (Table 3) was found in plots treated with control. Similar findings were reported by Kumar *et al.* (2020) in marigold, Kumar *et al.* (2015) in China Aster and Doddagoudar *et al.* (2004) in China Aster. Application of plants with GA_3@150 ppm registered more seed yield per plant (56.59 g.) while minimum seed yield per plant (16.20 g.) (Table 3) was found with spraying of control, above results are in conformity with Kumar *et al.* (2020) in marigold, Kumar *et al.,* (2015) in China aster. Significant increase inseed parameters like total seeds per head, weight of seeds per head, 1000 seed weight and seed yield per plant might be due to application of gibberellins may be promoted the production of hydrolyticen zymes to break down starchyendo sperm, which in turn affected the physiology of seed germination, vigour and seedling establishment. Metabolic changes caused by the use of gibberellins may have contributed to improvements in seed yield and quality parameters by influencing both quantity and quality to the desired level. Foliar spray of GA_3@ 150 improved the vegetative growth like height, plant spread, number of leaves and floral attributes like early initiation of flower bud, early flowering as well as maximum duration of flowering which produced morephoto-synthases,which would have been diverted to the sink and produced a higher yield of higher-quality seed in African marigolds.

CONCLUSION

The results showed that GA_3@150 ppm produced the best results for importantvegetative, floral such as plant height, number of leaves, number of branches per plant, days to first flower bud initiation, flower bud opening, duration of flowering, number of flowers per plant, number of flowers per bed. GA_3@ 150 ppm may bechosen and recommended for quality flower production, for better qualitative and quantitative seed production in West Bengal's Terai Region. The supply of flowers to market at regular basis is the key success to catch the proper market price as well as fulfil the demand of consumers. From the point of view, plant growth hormone GA_3 @ 150 ppm separately in the same field for regular supply of flowers to the market plus seed production.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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