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Effect of Plant Growth Retardants (Paclobutrazol, Alar, Maleic Hydrazide) on Growth, Flowering and Yield on African Marigold (*Tagetes erecta*) cv. Pusa Basanti under Open Field Conditions of Prayagraj

Mansi Arya [a*ϕ] and Urfi Fatmi [a#]

[a] Department of Horticulture (Floriculture and Landscaping), SHUATS, Prayagraj, Uttar Pradesh-211007, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The present experiment was carried out during March, 2022 to June, 2022 in Research Field, Department of Horticulture, SHUATS, Prayagraj. The research was conducted with an aim to identify the most suitable growth retardants and its appropriate dose under the agro climatic conditions of Prayagraj was carried out in Randomized Block Design (RBD), with three replications. Ten treatments were considered viz., Control (T_0), Paclobutrazol (PBZ) at 100 ppm (T_1), 150 ppm (T_2), 200 ppm (T_3); Maleic Hydrazide (MH) at 1000 ppm (T_4), 1500 ppm (T_5), 2000 ppm (T_6); Alar at 1000 ppm (T_7), 1500 ppm (T_8), 2000 ppm (T_9). From the experimental findings, it was observed that treatment PBZ at 100 ppm performed significantly better in most of the parameter like plant height (33.82 cm), plant spread (44.03 cm), number of primary branch (4.11), early bud initiation (33.6 days) and early flowering (50.6 days). The treatment MH at 1000 ppm performed significant for more fresh weight (4.28 g), flower diameter (4.07 cm), as well as shelf life (7.64 days). It also reported higher flower yield per plant (254.97 g), gross return (717093 Rs/ha), net return (426514 Rs/ha) and benefit: cost ratio (2.47). Through the study it can be conclude that PBZ at 100 ppm was better in vegetative parameter as well as early initiation and MH at 1000 ppm was good in producing higher yield when compared to other treatments.Include the recommendation based on results of the study.

ϕ M.Sc. Scholar;
 # Assistant Professor;
**Corresponding author: E-mail: mansiarya.9@gmail.com, mansiarya.97@gmail.com, aryamansi801@gmail.com;*

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1. INTRODUCTION

Marigold (*Tagetes erecta* L. family: Asteraceae) is native to south and Central America. It is one of the most popular and commercial flowering annuals cultivated in most of the states in India. It has great demand during various festivals for garland, cut flower and decorative purposes. It is suitable for potted plant, bedding, edging, garland making, religious offerings and for making different products. The genus Tagetes comprises about 33 species, of which the commonly cultivated species are *Tagetes erecta*, *Tagetes patula,* and *Tagetes minuta*. Amongst these, *Tagetes erecta* and *Tagetes patula* are more commonly grown for their ornamental values while the later for its high content of essential oil. African marigold and French marigold are of great horticultural importance and are commercially for their exquisite blooms. Among all the species of marigold. *Tagetes minuta* is the source of commercial "Tagetes Oil" used in industry. It is commercial cultivated in South Africa, where the species is also a useful pioneer plant in the reclamation of disturbed land. Flower of marigold is capitulum that has an inner disc floret of short and tubular petals and outer ray florets of being and thin petals.

The use of marigold is many folds, often referred to as, "Versatile crop with golden harvest." Marigolds produce thiophens, which are toxic to nematodes and used as trap crop in tomato, brinjal, tobacco etc. (Raghava, 2000). Marigold, not only cultivated as ornamental cut flower and landscape but also a source of carotenoid pigment for poultry fees to intensify yellow colour of egg yolks and broiler skin [1,2]. Apart from poultry industry, marigold dye is also used in textile, pharmaceutical industries, food supplements, cosmetics etc. as the offer several advantages over synthetic dyes from natural point of view, safety and eco-friendly in nature [3]. The principal pigment in the flower is xanthophyll particularly lutein which accounts for more than 80- 90% and is present in the form of esters of palmitic and myristic acid. Marigold occupies anti-helminthic, analgesic, anti-inflammatory, aromatic, bronchodilatory, digestive, diuretic, emmenagogue sedative and stomatic properties. Leaf extract is good remedy for earache. Flower extract is a good blood purifier, a cure for blood piles, ulcer and eye diseases [4-6]. The leaves of marigold plants are characterized by the presence of odoriferous oil. Hence, there is a great demand for natural colours of marigold in the international market. In India, the extraction of carotenoids on commercial scale is being done in Kerala and Andhra Pradesh states particularly in Cochin and Hyderabad respectively and it is being exported to Mexico [7,8]. Consequently, large areas in Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra are covered with contract cultivation of marigold (Raghava, 2000).

Growth and yield patterns are influenced by agro techniques. Among them, spacing played an important role for manipulating plant growth and flowering behaviour and seed yield [9]. Various chemicals are nowadays, being tries for controlling growth and flowering of ornamental plants with a view to have compact plants and also to stretch out or retard rate in order to supply their flower within the stipulated time. Flowers of African marigold can be used for extraction of 1-lemoene, Eocene, 1-linylaetate, 1-linauol. An extract obtained from the flowers is mixed with other ingredients in the preparation of an obtained which is used in curing ulcer [10].

Hormone application has been an essential part of flower cultivation. Within the broad group of plant hormones, some act as growth prompters while others act as growth retardants. Growth promoters as well as growth retardants have been used in floriculture to manipulate plant growth in a desired way [11].

In recent year, a number of plant growth retardants have been used in the field of agriculture for including more acceptable plant characteristics like compact growth, dwarfness, increase number of healthy branches and a greater number of quality flowers which are the desired traits in modern floriculture industry. Plant growth retardants are commonly use in the production of bedding plants to control plant growth and habit during production and to improve plant appearance and quality during marketing. In most of the flower crops, the seed yield is mainly dependent on number of flowers bearing branches which can be manipulated by checking vertical growth of plants. Growth regulators are used to overcome the factors limiting the growth and yield to harness maximum benefit from seed production. It is also observed that exogenous foliar application of growth regulators stimulates flowering,

pollination, fertilization and seed setting to get maximum seed yield [12].

India occupies 15 percent of the area for traditional flowers in the world, where major marigold producing states are Tamil Nadu, Andhra Pradesh, Maharashtra, West Bengal, Delhi, Uttar Pradesh and Uttarakhand. Karnataka is leading state is marigold with production of 49,777 tonnes of flower followed by Delhi (14,570 tonnes) and Orissa (1458 tonnes). It is always sold in the markets for daily worships and rituals and is and will always be the most cultivated and importance loose flower of India.

The objective of study was to enhance production of best quality loose marigold flowers by applying different growth retardants approaches. Moreover, our study aimed to determine the effects on growth, yield, and quality of carnation plants by application of selected growth retarding substances. And to analyse the possibilities for increasing income to farmers.

2. MATERIALS AND METHODS

The experiment was conducted at the Horticulture Research Field, Department of Horticulture, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj which is situated in the agro climatic zone (subtropical belt) of Uttar Pradesh. Prayagraj is situated at an elevation of 78 meters above sea level at 25.87° North latitude and 81.15° East longitudes. This region has a sub-tropical climate prevailing in the South-East part of UP with both the extremes in temperature, i.e., the winter and the summer. In cold winters, the temperature sometimes is as low as 32°F from December – January and very hot summer with the temperature reaching up to 115°F in May and June (SHUATS, 2022). The experiment was conducted from March, 2022 to July, 2022.

The experiment was laid out in Randomized Block Design (RBD) with single variety of African marigold i.e., Pusa basanti was selected for the evaluation. The seedlings were procured from Varanasi. The well-grown seedlings of varieties were transplanted into the main field with a spacing of 40 × 40 cm during March 2022. During transplanting, a handful of vermicompost was applied per pit. Light irrigation was done immediately after the transplanting of seedlings. Freshly prepared growth retardants were sprayed at different concentrations. The first spray was applied three weeks after transplanting, while second spray was scheduled at five weeks after transplanting. Five plants were randomly selected in the net plot area and tagged with labels in each treatment to record observation on growth and yield. Observations were made on various vegetative growth and flowering parameters. The data collected were analyzed using statistical methods.

3. RESULTS AND DISCUSSION

3.1 Performance of African Marigold Variety (Pusa Basanti) for Vegetative Parameters

Significantly, the taller plant height was recorded in the T_1 [PBZ @ at 100 ppm (33.82 cm)], followed by the T_2 [PBZ at 150 ppm (36.27 cm)]. While, shorter plant height was recorded in the treatment in the T_0 (39.88 cm). All these findings stated that plant growth retardants have prominent effect in controlling plant height. The reason for reduction in plant height due to Paclobutrazol treatments might be due to the inhibition of gibberellin synthesis, which caused reduction in stem elongation (Table 1). Similar findings were also obtained by Barett and Burtiska [13], Muhammad et al. [14]; Yawale et al. [15]; Singh (2001) in chrysanthemum; Patel [16] and Mann [17] in marigold and Singh and Bist (2003) in rose.

Significantly, the more plant spread was recorded in the T_1 [PBZ @ 100 ppm (44.03 cm)], which was found to be at par with the T_3 [PBZ @ 200 ppm (40.03 cm)], T_4 [MH @ 1000ppm (42.37cm)] and T_7 [ALAR @ 1000 ppm (42.13 cm)], followed by the T_9 [ALAR @ 2000 ppm (40.15 cm)] (Table 1). While, lesser plant height was recorded in the treatment in the T_0 (37.77 cm). Paclobutrazol suppresses apical dominance that produces greater number of main and secondary branches which resulted in increased plant spread. The results are corroboratory with the findings of Qiu and Liu (1984) in chrysanthemum; Sreekala et al. (2000) in crossandra and Mann [17] in marigold.

Significantly, the more number of primary branches was recorded in T_1 [PBZ @ 100 ppm (4.11)], which was found to be at par with the T_6 [MH @ 2000 ppm (3.27)], T_7 [ALAR @ 1000 ppm (3.20)] and T_0 (3.27), followed by the T_8 [ALAR @ 1500 ppm (2.87)]. While, lesser plant height was recorded in the T_8 [MH @ 1500 ppm (2.57)

(Table 1)]. The number of branches is found to highest in Paclobutrazol treatment, it might due to reduction in the apical dominance (Henrsel, 1985), which induces interval growth of lateral growth and ultimately increases the number of branches. Similar findings have also been reported by Mohammad (1988) in cosmos; Patel [16] and Mann [17] in marigold and Singh (2001) in chrysanthemum.

3.2 Performance of African Marigold Variety (Pusa Basanti) for Floral Parameters

Significantly, the less days taken to flower bud initiation was recorded in T_1 [PBZ @ 100 ppm (33.6)], which was found to be at par with the T_2 [PBZ @ 150 ppm (34.1 days)], T_3 [PBZ @ 200 ppm (33.7 days)], T_4 [MH @ 1000 ppm (34.1 days)] T_5 [MH @ 1500 (34.5 days)], T_6 [MH @ 2000 ppm (35.1 days)]. While highest days took for flower bud opening was in T_0 [(37.5 days)] (Table 2).

Significantly, the less days taken to 1st flower opening was recorded in T_1 [PBZ @ 100 ppm (50.6)], which was found to be at par with the T_2 [PBZ @ 150 ppm (34.1 days)], T_3 [PBZ @ 200 ppm (33.7days)], T_7 [MH @ 1000 ppm (34.1 days)], T_5 [MH @ 1500 ppm (34.5 days)], T_6 [MH @ 2000 ppm (35.1 days)], whereas highest days took for flower bud opening was in T_0 (37.5 days). Food reserves at initial stages due to reduction in plant height and increases in number of leaves and leaf area resulted in attaining early reproductive stage and bud initiation with Paclobutrazol treated plants. This reserves food has been utilised for reproductive purpose with a restriction on vegetative growth. Similar results were obtained by Narayan Reddy (1978) and Kumar and Kumar [18] in balsam.

Significantly, highest duration of flowering was recorded in T_8 [Alar @ 1500 ppm (61.8 days)], which was found to be at par with the T_9 [Alar @ 2000 ppm (60.4 days)]. While, lesser duration of flowering was recorded in the T_0 (48.5 days). Alar improved the longevity by maintaining the levels of chlorophyll, protein, and RNA content of leaves at higher level for a longer duration suppressing the senescence. Similar results were reported by Joshi and Reddy (2020).

Significantly, the more number of flowers per plant was recorded in T_4 [MH @ 1000 ppm (67.8)], which was found to be at par with the T_1 [PBZ @ 100 ppm (65.8)], followed by the T_5 [MH @ 1500ppm (55.3)]. While, lesser number of flowers per plant was recorded in the treatment in the T_0 (38.7). The increased in number of flowers per plant might be due to increase in number of branches and also removal of apical dominance due to MH which ultimately enhanced the flower production. Kumar and Kumar [18] in balsam, Anburni and Ananth [19] in nerium and Navale et al. [20] in chrysanthemum reported maximum number of flowers due to foliar spray of maleic hydrazide.

Significantly, the highest flower diameter was recorded in treatment [MH @ 1500 ppm (4.07 cm)], which was found to be at par with the treatment [ALAR @ 1500 ppm (3.84cm)], [PBZ @ 100 ppm (3.94cm)] and [ALAR @ 2000 ppm (4.03cm)] followed by the treatment [MH @ 1000 ppm (3.76 cm)]. While, lesser flower diameter was recorded in the treatment in the treatment (3.45 cm). These findings are in consonance with Kumar et al. [21] in African marigold, Malik et al. [22] in dahlia.

Significantly, more fresh weight was recorded in T_4 [MH @ 1000 ppm (4.28 g)], which was found to be at par with the T_7 [ALAR @ 1000 ppm (3.96 g)], T_1 [PBZ @ 100 ppm (3.88)], T_9 [ALAR @ 2000 ppm (3.83 g)], T_5 [MH @ 1500 ppm (3.71 g)], T_2 [PBZ @ 200 ppm (3.69 g)], T_8 [ALAR @ 1500 ppm (3.52 g)]. While, lesser fresh weight was recorded in the T_0 (3.06 g). It might be due to higher flower diameter and accumulation of more food materials. The results are in agreement with result of Yawale et al. [15] in chrysanthemum and Singh et al, (2002) and Singh and Bist (2003) in rose.

Significantly, higher shelf life was recorded in T_4 [MH @ 1000 ppm (7.64)], which was found to be at par with T_5 [MH @ 1500 ppm (6.60)] and T_9 [ALAR @ 2000 ppm (6.44)], While, lesser shelf life was recorded in the T_0 (3.49). The study revealed that the MH in higher concentration increased the shelf life of the flowers and that might be because of reduced metabolism and respiration Navale [20]. Similar effect of M.H on extension of shelf life were recorded by Dutta et al. [23] and Mitali and Talukdar [24] in chrysanthemum.

Table 1. Effect of plant growth retardants on vegetative parameters of African marigold

Treatment	Plant height (cm)			Plant spread (cm)			Number of primary branches
	15 days	30 days	45 days	15 days	30 days	45 days	
T_0 Control	39.8	41.95	44.44	31.53	36.40	37.77	3.27
T_1 PBZ@ 100 ppm	29.51	31.44	33.82	33.81	39.47	44.03	4.11
T_2 PBZ@ 150 ppm	31.48	33.60	36.27	31.21	34.76	37.88	2.77
T_3 PBZ@ 200 ppm	34.08	36.77	39.21	32.36	37.62	40.66	3.60
T_4 MH@ 1000 ppm	38.58	40.71	43.08	34.33	38.32	42.37	4.00
T_5 MH@ 1500 ppm	32.67	36.86	38.62	31.17	36.15	39.05	2.57
T_6 MH@ 2000 ppm	34.72	37.16	39.91	31.39	37.89	38.35	3.27
T_7 ALAR@ 1000 ppm	39.25	41.14	43.30	33.47	37.42	42.13	3.20
T_8 ALAR@ 1500 ppm	37.63	39.63	42.08	32.06	38.38	39.57	2.87
T_9 ALAR@ 2000 ppm	34.21	36.86	39.56	31.77	S	40.15	2.60
F-TEST	S	S	S	S	S	S	S
SE.d (±)	0.84	1.01	0.92	0.76	1.01	1.00	0.25
CD (5%)	1.79	2.14	1.94	1.61	2.14	2.11	0.54
CV	2.95	3.29	2.81	2.88	3.32	3.04	9.68

Table 2. Effect of plant growth retardants on floral parameters of African marigold

Treatment	Days to first flower bud initiation	days to first flowering	Duration of flowering	No. of flowers per plant	Flower diameter (cm)	Fresh weight (g)	Shelf life (days)
T_0 Control	37.5	58.4	48.5	38.7	3.45	3.06	3.49
T_1 PBZ@ 100 ppm	33.6	50.6	52.8	65.8	3.94	3.88	5.26
T_2 PBZ@ 150 ppm	34.1	50.8	52.0	55.0	3.55	3.06	4.31
T_3 PBZ@ 200 ppm	33.7	51.1	51.9	54.9	3.69	3.69	4.45
T_4 MH@ 1000 ppm	34.1	52.4	56.3	67.8	3.76	4.28	7.64
T_5 MH@ 1500 ppm	34.5	53.1	54.1	55.4	4.07	3.71	6.60
T_6 MH@ 2000 ppm	35.1	54.9	55.9	49.2	3.69	3.11	6.19
T_7 ALAR@ 1000 ppm	36.5	58.3	58.4	55.3	3.69	3.96	5.71
T_8 ALAR@ 1500 ppm	37.0	56.5	61.8	45.4	3.84	3.52	6.13
T_9 ALAR@ 2000 ppm	36.3	55.3	60.4	47.6	4.03	3.83	6.44
F-TEST	S	S	S	S	S	S	S
SE.d (±)	0.76	0.92	0.85	1.17	0.12	0.33	0.67
CD (5%)	1.61	1.95	1.72	2.48	0.25	0.68	1.42
CV	2.65	2.09	6.93	2.68	3.90	14.63	11.11

Table 3. Effect of plant growth retardants on yield parameters and economic of African marigold

Treatment	Flower yield per plant	Flower yield per ha	Cost of cultivation	Gross return	Net return	Benefit cost ratio
T_0 Control	141.79	79.76	286495	398793	112298	1.39
T_1 PBZ@ 100 ppm	228.36	128.45	327509	642271	314762	1.96
T_2 PBZ@ 150 ppm	196.86	110.73	348128	553668	205540	1.59
T_3 PBZ@ 200 ppm	208.36	117.20	368524	586012	217488	1.59
T_4 MH@ 1000 ppm	254.97	143.42	290579	717093	426514	2.47
T_5 MH@ 1500 ppm	210.22	118.25	294663	591234	296571	2.01
T_6 MH@ 2000 ppm	156.20	87.86	298747	439303	140556	1.47
T_7 ALAR@ 1000 ppm	186.78	105.06	297747	525309	227562	1.76
T_8 ALAR@ 1500 ppm	158.21	88.99	308999	444965	135966	1.44
T_9 ALAR@ 2000 ppm	195.28	109.85	320245	549225	228980	1.72
F-TEST	S	S				
SE.d (±)	1.12	0.63				
CD (5%)	2.38	1.33				
CV	0.71	0.70				

3.3 Performance of African Marigold Variety (Pusa Basanti) for Yield Parameters

Significantly, the higher flower yield per plant was recorded in T_4 [MH at1000 ppm (254.97 g)], followed by the T_1 [PBZ at 100 ppm (228.36 g)]. While, lesser flower yield per plant was recorded in the T_0 (141.79 g). The higher flower yield per ha was recorded in T_4 [MH at 1000 ppm (143.42 q per ha)], followed by the T_1 [PBZ 100 at ppm (128.45 q per ha)]. While, lesser flower yield per plant was recorded in the (79.76 q / ha) (Table 3). Similar variation was observed by Ahmad et al*.* [25] in carnation, Khan et al*.* (2012) in African marigold, Moon et al*.* [26] in gaillardia. Abbas et al*.* (2007) in Rosa damascene.

3.4 Performance of African Marigold Variety (Pusa Basanti) for Economic Parameters

Significantly, the higher cost of cultivation was recorded in the T_3 [PBZ at 200 ppm (368524 Rs. per ha)], followed by the T_2 [PBZ at 150 ppm (348128 Rs. per ha)]. While, lesser cost of cultivation was recorded in the T_0 (286495 Rs. per ha). Likewise, gross return was found higher in the T_4 [MH @ 1000 ppm (717093.8 Rs. per ha)], followed by the T_1 [PBZ at 100 ppm (642271.9 Rs. per ha)]. While, lesser gross return was recorded in the T_0 (398793.5 Rs. per ha). Net return were found higher in the T_4 [MH at 1000 ppm (426514.8 Rs. per ha)], followed by the T_1 [PBZ at 100 ppm (314762.9 Rs. Per ha)]. While, lesser net return was recorded in the T_0 (112298.7 Rs. Per ha). The benefit cost ratio was found higher in the T_4 [MH at 1000 ppm (2.47)], followed by the T_1 [PBZ at 100 ppm (1.96)]. While, lesser benefit cost was recorded in the T_0 (1.39) (Table 3).

4. CONCLUSION

Based on the experiment, it is concluded that Paclobutrazol at 100 ppm is superior for reducing the plant height, increasing plant spread, number of primary branches, early bud initiation and early flowering. The treatment Maleic hydrazide at 100 ppm performed significantly better in terms of fresh weightfresher, flower diameter as well as shelf life. It also reported higher flower yield per plant, gross return, net return and benefit: cost ratio. Hence, for controlling vegetative growth and for earliness Paclobutrazol at 100 ppm can be recommended and for higher yield as well as Benefit: Cost ratio Maleic Hydrazide at 1000 ppm can be recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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