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Effect of plant growth retardants and their time of application on flower quality attributes of African marigold (*Tagetes erecta* L.)

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Abstract
The present investigation was conducted during *rabi* season of 2018-19 and 2019-20 at Horticultural Research cum Instructional Farm, Department of Floriculture and Landscape Architecture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The field experiments was laid out in Factorial Randomized Block Design with three replications having twenty one treatment combinations of two plant growth retardants their three doses each *i.e.* Paclobutrazol (PBZ) at 50, 100 and 150 ppm and Cycocel (CCC) at 500, 750 and 1000 ppm along with water spray (control) as factor A and three time of application *viz*. 30 DAT, 45 DAT and 30 and 45 DAT as factor B. Among the different treatments of plant growth retardants the significantly maximum vase life (days) and self life (days) were observed with application of Paclobutrazol (PBZ) at 50 ppm during both the years as well as on mean basis. Whereas, significantly maximum flower diameter (cm) and fresh weight of flower (g) of African marigold were recorded with application of Paclobutrazol (PBZ) at 150 ppm during both the years and on mean basis. The result revealed that among the time of application of plant growth retardants at 30 DAT recorded significantly highest vase life (days), self life (days), flower diameter (cm) and fresh weight of flower (g) of marigold during both the years and on mean basis.

Keywords: cycocel, marigold, paclobutrazol, quality attributes

Introduction
Marigold (*Tagetes erecta* L.) is an important commercial flower of India, belongs to family Asteraceae (Compositeae). Marigold is one of the most popular flowers in our country. Because of their ease in cultivation, wide adaptability to varying soil and climatic conditions, long duration of flowering and attractively coloured flowers, which is used for religious purpose, decoration and beautification of gardens. The carotenoid extracted from marigold petals are used in poultry feed to intensify yellow colour of egg yolk. In Chhattisgarh, marigold is cultivated in an area of 4501 ha with a production of 32192 MT (Anonymous 2017) [1]. Marigold is one of the dominating flowers in the flower trade market of Chhattisgarh and there is need to regulate flowering as per the market demand. The plant growth retardants have the capacity to regulate the flowering of marigold and growth retardants suppress the apical vegetative growth which increases branches and induce early flower bud initiation. Paclobutrazol and Cycocel are two well-known growth retardants. Paclobutrazol reduced plants height, increase number of primary and secondary branches and flowers in different crops (Boldt, 2008) [2]. The application of cycocel checks the apical dominance which encourages plant spreading, slows down the cell division and cell elongation in meristematic tissues of shoot and regulate the plant height without formative effects and change the morphology and physiology of the plant.

Method and Material
The present investigation was conducted during *rabi* season of 2018-19 and 2019-20 at Horticultural Research cum Instructional Farm, Department of Floriculture and Landscape Architecture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The field experiments were laid out in Factorial Randomized Block Design with three replications having twenty one treatment combinations of two plant growth retardants their three doses each *i.e.* Paclobutrazol (PBZ) at 50, 100 and 150 ppm and Cycocel (CCC) at 500, 750 and 1000 ppm along with water spray (control) as factor A and three time of application *viz*. 30 DAT, 45 DAT and 30 and 45

DAT as factor B. Seedlings of African marigold were raised in the nursery bed. Four weeks old seedlings were planted in the experimental field.

Result

Vase life (Days)

Effect of plant growth regulators

The data on vase life of marigold flower cv. 'Pusa narangi gainda' as significantly influenced by different plant growth retardants are given in Table 1. Among different plant growth retardants, treatment G_1: PBZ 50 ppm noted significantly longest vase life (6.00, 7.11 and 6.56 days) during both the years and on mean basis, respectively, but it was statistically similar to treatments G_2: PBZ 100 ppm (5.78, 6.83 and 6.31 days), G_3: PBZ 150 ppm (5.53, 6.78 and 6.16 days) and G_6: CCC 1000 ppm (5.78, 7.00 and 6.39 days) during both the years as well as on mean basis, respectively. Whereas, treatment G_0: water spray gave minimum vase life (5.09, 5.68 and 5.38 days) during both the years and on mean basis, respectively.

Effect of time of application of growth retardants

Different application time of plant growth retardants observed significant impact on vase life of marigold flower cv 'Pusa narangi gainda', during both the years as well as on mean basis and data are presented in Table 1. The significantly maximum vase life (5.81, 6.78 and 6.30 days) was noted with treatment D_1: application at 30 DAT, but it was *at par* to treatment D_3: application at 30 and 45 DAT (5.62, 6.56 and 6.09 days) during both the years and on mean basis, respectively. However, treatment D_2: application at 45 DAT, gave minimum vase life of marigold flower (5.28, 6.22 and 5.75 days) during both the years as well as on mean basis, respectively.

Interaction effect

The interaction effects between plant growth retardants and their time of application was found non-significant with regards to vase life of African marigold during both the years and on mean basis.

Self life (Days)

The data on self life of African marigold flower as influenced by plant growth retardants and their time of application are presented in Table 1

Table 1: Effect of plant growth retardants and their time of application on vase life (days) and self-life (days) of African marigold

Treatment	Vase life (days)			Self-life (days)		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean
Plant growth retardant (G)						
G_1	6.00	7.11	6.56	5.56	6.03	5.79
G_2	5.78	6.83	6.31	5.31	5.91	5.61
G_3	5.53	6.78	6.16	5.03	5.89	5.46
G_4	5.41	5.88	5.64	4.69	5.11	4.90
G_5	5.42	6.37	5.89	4.83	5.23	5.03
G_6	5.78	7.00	6.39	5.28	5.52	5.40
G_0	5.09	5.68	5.38	4.06	4.59	4.32
SEm±	0.18	0.22	0.14	0.22	0.23	0.15
CD (P=0.05)	0.52	0.63	0.40	0.62	0.65	0.44
Time of application (D)						
D_1	5.81	6.78	6.30	5.37	5.79	5.58
D_2	5.28	6.22	5.75	4.56	5.24	4.90
D_3	5.62	6.56	6.09	4.97	5.38	5.17
SEm±	0.12	0.14	0.09	0.14	0.15	0.10
CD (P=0.05)	0.34	0.41	0.26	0.41	0.43	0.29
Interaction						
G_1D_1	6.67	7.67	7.17	6.17	6.50	6.33
G_1D_2	5.33	6.67	6.00	4.83	5.77	5.30
G_1D_3	6.00	7.00	6.50	5.67	5.83	5.75
G_2D_1	6.00	7.17	6.58	5.83	6.17	6.00
G_2D_2	5.33	6.33	5.83	4.83	5.67	5.25
G_2D_3	6.00	7.00	6.50	5.27	5.90	5.58
G_3D_1	5.67	6.83	6.25	5.50	6.17	5.83
G_3D_2	5.53	6.33	5.93	4.77	5.67	5.22
G_3D_3	5.40	7.17	6.28	4.83	5.83	5.33
G_4D_1	5.67	6.00	5.83	4.90	5.17	5.03
G_4D_2	5.00	5.90	5.45	4.33	4.83	4.58
G_4D_3	5.57	5.73	5.65	4.83	5.33	5.08
G_5D_1	5.53	6.77	6.15	5.17	5.50	5.33
G_5D_2	5.40	6.00	5.70	4.50	4.93	4.72
G_5D_3	5.33	6.33	5.83	4.83	5.27	5.05
G_6D_1	6.00	7.33	6.67	5.83	6.17	6.00
G_6D_2	5.33	6.67	6.00	4.83	5.07	4.95
G_6D_3	6.00	7.00	6.50	5.17	5.33	5.25
G_0D_1	5.17	5.70	5.43	4.17	4.83	4.50
G_0D_2	5.03	5.67	5.35	3.83	4.77	4.30
G_0D_3	5.07	5.67	5.37	4.17	4.17	4.17
SEm±	0.31	0.38	0.24	0.38	0.39	0.27
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Effect of plant growth regulators
The significantly maximum self life (5.56, 6.03 and 5.79 days) was recorded with the treatment G_1: PBZ 50 ppm, but it was statistically similar to treatment G_2: PBZ 100 ppm (5.31, 5.91 and 5.61 days), treatment G_3: PBZ 150 ppm (5.03, 5.89 and 5.46 days) and treatment G_6: CCC 1000 ppm (5.28, 5.52 and 5.40 days) during both the years as well as on mean basis, respectively. However, the lowest self life (4.06, 4.59 and 4.32 days) was noted with treatment G_0: water spray during both the years as well as on mean basis, respectively.

Effect of time of application of growth retardants
As regards to time of application of growth retardants, treatment D_1: application at 30 DAT show significantly higher self life (5.37, 5.79 and 5.58 days) as compared to rest of the other treatments during both the years as well as on mean basis, respectively, but it was *at par* to treatment D_3: application at 30 and 45 DAT (4.97 and 5.38 days) during both the years, respectively. The minimum self life (4.56, 5.24 and 4.90 days) was noted with treatment D_2: application at 45 DAT during both the years as well as on mean basis, respectively.

Interaction effect
The interaction effects between plant growth retardants and their time of application was found non-significant with regards to self life of African marigold during both the years and on mean basis.

Flower diameter (cm)
The data on flower diameter was recorded and presented in Table 2. Plant growth retardants gave significant influence on flower diameter of marigold flower during both the years as well as on mean basis.

Effect of plant growth regulators
The significantly maximum flower diameter (5.95, 6.02 and 5.99 cm) was registered with treatment G_3: PBZ 150 ppm, during both the years and on mean basis, respectively, but it was statistically similar with treatment G_2: PBZ 100 ppm (5.74, 5.87 and 5.80 cm), G_5: CCC 750 ppm (5.60, 5.81 and 5.70 cm) and treatment G_6: CCC 1000 ppm (5.76, 5.87 and 5.81cm), during both the years and on mean basis, respectively. While, the minimum flower diameter (5.09, 5.38 and 5.24 cm) was recorded in treatment G_0: water spray during both the years and on mean basis, respectively.

Effect of time of application of growth retardants
The data on flower diameter of marigold as influenced by time of application of growth retardants are given in Table 2. Among different time of application plant growth retardants, treatment D_1: application at 30 DAT gave significantly highest flower diameter (5.74, 5.91 and 5.82 cm), followed by D_3: application at 30 and 45 DAT (5.59, 5.73 and 5.66 cm), during both the years as well as on mean data basis, respectively. While, the least flower diameter (5.38, 5.56 and 5.47 cm) was noticed with treatment D_2: application at 45 DAT during both the years as well as on mean basis, respectively.

Interaction effect
The interaction effects between plant growth retardants and their time of application was found non-significant with regards to flower diameter of African marigold during both the years and on mean basis.

Fresh weight of flower (g)
At perusal of data presented in Table 2, revealed that the fresh weight of marigold flower was significantly influenced by plant growth retardants and their time of application during both the years as well as on mean basis.

Table 2: Effect of plant growth retardants and their time of application on flower diameter (cm) and fresh weight of flower (g) of African marigold

Treatment	Flower diameter (cm)			Fresh weight of flower (g)		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean
Plant growth retardant (G)						
G_1	5.46	5.61	5.54	7.28	8.96	8.12
G_2	5.74	5.87	5.80	7.58	9.29	8.43
G_3	5.95	6.02	5.99	8.29	9.92	9.11
G_4	5.37	5.59	5.48	7.26	8.28	7.77
G_5	5.60	5.81	5.70	7.57	9.41	8.49
G_6	5.76	5.87	5.81	8.01	9.79	8.90
G_0	5.09	5.38	5.24	6.87	7.94	7.41
SEm±	0.14	0.14	0.10	0.23	0.30	0.19
CD (P=0.05)	0.39	0.40	0.29	0.65	0.87	0.55
Time of application (D)						
D_1	5.74	5.91	5.82	7.79	9.36	8.57
D_2	5.38	5.56	5.47	7.24	8.68	7.96
D_3	5.59	5.73	5.66	7.62	9.22	8.42
SEm±	0.09	0.09	0.07	0.15	0.20	0.13
CD (P=0.05)	0.25	0.26	0.19	0.42	0.57	0.36
Interaction						
G_1D_1	5.79	5.85	5.82	7.87	9.17	8.52
G_1D_2	5.24	5.47	5.36	6.93	8.47	7.70
G_1D_3	5.36	5.51	5.43	7.03	9.23	8.13
G_2D_1	5.78	6.14	5.96	7.83	10.10	8.97
G_2D_2	5.57	5.55	5.56	7.20	8.23	7.72
G_2D_3	5.85	5.91	5.88	7.70	9.53	8.62
G_3D_1	6.00	6.17	6.09	8.53	10.13	9.33
G_3D_2	5.70	5.86	5.78	7.87	9.67	8.77

G_3D_3	6.16	6.02	6.09	8.47	9.97	9.22
G_4D_1	5.71	5.91	5.81	7.37	8.30	7.83
G_4D_2	5.02	5.33	5.18	7.13	8.17	7.65
G_4D_3	5.37	5.54	5.46	7.27	8.37	7.82
G_5D_1	5.78	5.85	5.81	7.70	9.73	8.72
G_5D_2	5.43	5.73	5.58	7.27	9.17	8.22
G_5D_3	5.59	5.84	5.72	7.73	9.33	8.53
G_6D_1	5.90	6.01	5.96	8.30	10.10	9.20
G_6D_2	5.65	5.70	5.68	7.47	9.13	8.30
G_6D_3	5.71	5.90	5.81	8.27	10.13	9.20
G_0D_1	5.19	5.43	5.31	6.90	7.97	7.43
G_0D_2	5.04	5.31	5.18	6.83	7.90	7.37
G_0D_3	5.06	5.40	5.23	6.87	7.97	7.42
SEm±	0.23	0.24	0.17	0.39	0.52	0.36
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Effect of plant growth retardants

Among different plant growth retardants, treatment G_3: PBZ 150 ppm observed significantly maximum fresh weight of flower (8.29, 9.92 and 9.11 g) during both the years and on mean basis, respectively, but it was statistically similar to treatment G_2: PBZ 100 ppm (9.29 g) and treatment G_5: CCC 750 ppm (9.41 cm) during second year (2019-20) of investigation and treatment G_6: CCC 1000 ppm (8.01, 9.79 and 8.90 g) during both the years and on mean basis, respectively. One the other hand, the minimum fresh weight of flower (6.87, 7.94 and 7.41 g) was observed with treatment G_0: water spray during both the years and on mean basis, respectively.

Effect of time of application of plant growth retardants

As regards to time of application of growth retardants, treatment D_1: application at 30 DAT show significantly highest value of fresh weight of flower (7.79, 9.36 and 8.57 g), but it was *at par* to treatment D_3: application at 30 and 45 DAT (7.62, 9.22 and 8.42 g) during both the years as well as on mean basis, respectively. Whereas, minimum fresh weight of flower (7.24, 8.68 and 7.96 g) was observed with treatment D_3: application at 45 DAT during both the years as well as on mean basis, respectively.

Interaction effect

The interaction effects between plant growth retardants and their time of application was found non-significant with regards to fresh weight of African marigold flower during both the years and on mean basis.

Discussion of quality attributes

Effect of plant growth retardants

Increased vase life of African marigold flower was significantly influenced by plant growth retardants, during the period of investigation. Application of PBZ increased vase life which might be due to reduced physiological weight loss and more water uptake by marigold flowers. Restricted respiration due to the inhibitory action of PBZ might have increased the vase life of flowers. Similar findings were also obtained by Dani *et al.* (2010) [3] in African marigold, Munikrishnappa and Chandrashekar (2014) [8] in China aster and Nellipalli and Pal (2018) [9] in tuberose. The results clearly revealed that there was longer shelf life of African marigold flowers reported by PBZ treatment. Higher shelf life might be due to reduced ethylene production by reducing the bio-chemical process of ethylene production, which result in prolong self life of African marigold. Similar findings were also obtained by Maan (2003) [6] in African marigold, Khan and Pal (2009) [4] in tuberose and Nellipalli and Pal (2018) [9] in tuberose. Flower diameter and fresh weight were significantly influenced by plant growth retardants, during the period of investigation. The maximum flower diameter and fresh weight of African marigold flower was obtained with the application of PBZ. Greater flower diameter and fresh weight might be due to an increase in the length of floret and pedicles accompanied by an increased number of petals. The above results are in conformity with the findings reported by Singh (2002) [10] in rose, Khan and Pal (2009) [4] in tuberose, Youssef and El-Aal (2013) [12] in *Tabernaemontana coronaria* and Nellipalli and Pal (2018) [9] in tuberose.

Effect of time of application

The self life and vase life of the marigold flower increase with the application of plant growth retardants at 30 days after transplanting this might be because of the reason that, application of the plant growth retardants at the correct stage of the plant growth. Higher shelf life and vase life might be due to reduced physiological weight loss by flowers. Restricted respiration due to inhibitory action of retardant might have increased the shelf life and vase life of marigold flower. The above results can be conformity with findings of Kumar (2017) [5] in marigold cv. 'Pusa narangi gainda.'

Application of plant growth retardants at 30 after transplanting improved flowering quality characters (like flower diameter and flower weight) might be due to higher photosynthetic ability since the juvenile phase as well as better absorption of nutrient through improved growth leading to development of higher C: N ratio resulting improved flower diameter and flower weight. The results of experimental findings are in accordance with the findings of Vaghasia and Polara (2015) in Chrysanthemum, Kumar (2017) [5] in marigold cv. 'Pusa narangi gaind.' and Majeed *et al*. (2017) [7] in marigold.

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