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Effect of plant growth regulators on growth, yield and quality of chrysanthemum (*Chrysanthemum morifolium* Ramat.)

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Abstract

This investigation was conducted with the aim to find out the effect of plant growth regulators on growth, yield and quality of chrysanthemum (*Chrysanthemum morifolium* Ramat.). The experiment was laid out in a Randomized Block Design (RBD) with sixteen treatments including various plant growth regulators with different concentration *viz.* GA_3, NAA, SA (100, 150 and 200 ppm each), Triacontanol (10, 20 and 30 ppm) and CCC (500, 1000 and 2000 ppm) along with control (water spray). The results revealed that among various treatments, maximum plant height at 60 and 90 days after transplanting was observed with treatment GA_3 @ 200 ppm (32.51 cm and 63.37 cm, respectively). Whereas, maximum number of branches per plant (8.07) and plant spread (36.25 cm and 35.14 cm in N-S and E- W, respectively) were recorded in treatment CCC @ 2000 ppm. Significantly earliest bud appearance (58.07 days), first flower opening (83.73 days) and full blooming (100.67 days) was recorded with GA_3 @ 200 ppm which was at par with treatment GA_3 @ 150 ppm for all these characters (60.13 days, 88.73 days and 102.13 days for bud appearance, first flower opening and full blooming, respectively). Significantly maximum number of flowers per plant (87.60) were recorded with the application of treatment CCC @ 2000 ppm. Significantly maximum weight of flowers per plant (279.49 g), flower yield per plot (2.38 kg) and per hectare (293.27 q) was obtained with application of 200 ppm GA_3. Moreover, quality parameters like flower diameter (6.04 cm) and weight of individual flower (3.40 g) were also recorded maximum with the application of GA_3 @ 200 ppm. Based on economics, among all the treatments maximum benefit cost ratio (3.70) was found with GA_3 @ 200 ppm.

Keywords: Chrysanthemum, growth, Flowers, Plant growth regulators and GA_3

Introduction

Chrysanthemum (*Chrysanthemum morifolium* Ramat.) belongs to the family Asteraceae and ranks second in popularity next only to the rose. Chrysanthemum crop getting popularity day by day in Gujarat due to its ease in cultivation, high returns and market demand. Due to its diverse flower shape, chrysanthemum can be used as pot plants for beautifying indoors and outdoors, as cut flowers for making bouquets and vase decoration, loose flowers are generally used for making garland and wreaths which are used in marriages, festivals, religious offerings and death rituals. Loose flowers comprise an important part in Indian floriculture trade. Chrysanthemum is one of the most important loose flower crops which is being cultivated and traded throughout country. The growth and yield of plant is mainly influenced by two major factors *viz*., genetic factors and management factors, however regulating plant growth by the application of PGRs constitute the third most important advances in agro technology for improving growth, flowering and quality parameters in flower crops (Navale *et al*., 2010) [16]. The plant growth regulators are the compounds that in minor amount modify the physiological processes of plants and ultimately alter the yield and quality of plants. GA_3 influences a range of developmental process in plants life like germination, breaking dormancy, stem elongation, flowering, sex expression, enzyme induction and flower senescence (Mujadidi *et al*., 2019) [15]. NAA stimulates the cell division, cell enlargement and cell elongation in apical region of the plant. Triacontanol increases cell division rates, which produces large root and shoot mass, activates secondary messengers leading to enhance enzymatic activities, improve protein synthesis, promotes flowering and earlier crop maturity. SA plays an important role in photosynthesis, transpiration, ion uptake and transport in plants. The term 'growth retardant' is used for cycocel (CCC) because it slows the cell division and cell elongation in shoot tissues and regulates plant height physiologically without formative effect.

Determining increasing the crop productivity and quality with prudent use of available inputs without affecting the soil health is considered important goal and thus, it is an obligatory to find out the response of this crop to different plant growth regulators. Keeping this in mind the present investigation was carried out to find out the Effect of plant growth regulators on growth, yield and quality of chrysanthemum (*Chrysanthemum morifolium* Ramat.).

Materials and Methods

A field experiment on chrysanthemum var. Ratlam Selection was conducted during August 2021 to January 2022 at College Farm, College of Horticulture, S. D. Agricultural University, Jagudan, Gujarat, (India). Rooted cuttings of chrysanthemum variety Ratlam Selection were transplanted on the raised beds (1.5 m × 1.5 m) at a spacing of 30 cm × 30 cm. The experiment was laid out in Randomized Block Design (RBD) with total sixteen treatments *viz*. control (water spray) (T_1), GA_3 @ 100 ppm (T_2), **GA_3 @ 150 ppm (T_3)**, GA_3 @ 200 ppm (T_4), NAA @ 100 ppm (T_5), NAA @ 150 ppm (T_6), NAA @ 200 ppm (T_7), Triacontanol @ 10 ppm (T_8), Triacontanol @ 20 ppm (T_9), Triacontanol @ 30 ppm (T_{10}), SA @ 100 ppm (T_{11}), SA @ 150 ppm (T_{12}), SA @ 200 ppm (T_{13}), CCC @ 500 ppm (T_{14}), CCC @ 1000 ppm (T_{15}) and CCC @ 2000 ppm (T_{16}). Foliar application of plant growth regulators was done at 40 days after transplanting. The experiment was laid out in a Randomized Block Design and replicated thrice in open field condition. Observations of different parameters *viz*. growth, flowering, yield and quality parameters were recorded and analyzed statistically. Net return and benefit: cost ratio were calculated by using the formulas given below.

Net returns (₹/ha) = Gross returns (₹/ha) − Total cost of cultivation (₹/ha)

$$\text{Benefit Cost ratio} = \frac{\text{Net returns (₹/ha)}}{\text{Total cost of cultivation (₹/ha)}}$$

Results and discussion

Growth parameters

The growth chracters of chrysanthemum viz. plant height (cm) (60 and 90 days after transplanting), number of branches per plant and plant spread (N-S and E-W) (cm) were influenced by various treatments and number of suckers per plant found non- significant (Table 1). Among the different treatments significantly maximum plant height at 60 and 90 DAT (32.51 cm and 63.37 cm, respectively) was observed with the treatment T_4 *i.e*. GA_3 @ 200 ppm. Increase in the concentration of GA_3 has increased the plant height as evident from the data recorded at various stages of plant growth and highest concentration (GA_3 @ 200 ppm) resulted in maximum plant height. This might be attributed to the capacity of GA_3 to induce mRNA synthesis pertaining to hydrolytic enzymes and to increase cell enlargement, eventually leading to increased length of internodes. Exogenous GA_3 promotes mitotic activity in the apical zone, thereby increasing both the rate of cataphyll formation and giving rise to a higher and wider apical meristem (McDonald and Little, 2006) [12]. Therefore, the increase in plant height might be due to the rapid elongation of internodes by both cell division and cell elongation. The present findings are in line with earlier findings of Kudmate *et al*. (2016) [7] in annual chrysanthemum, Muhammad *et al*. (2016) [14] in chrysanthemum and Imandi and Reddy (2017) [5] in marigold. Whereas, significantly maximum number of branches per plant (8.07) was recorded with the foliar application of 2000 ppm CCC (T_{16}) plant growth retardants are regularly applied in commercial ornamental plant production to improve ornamental and aesthetic characteristics of plants, including stem girth and branching. Plant growth retardants affect the plant height by suppression of apical dominance which induce the lateral vegetative bud growth which leads to increase in the number of branches. Increase in the number of branches per plant with application of CCC might be due to check in apical dominance which could be due to lower level of endogenous production of auxin which in turn induces the sprouting of vegetative buds (Cathey and Stuart, 1961) [4]. The diversion of photosynthates towards the axillary buds might have increased the number of branches. Qureshi *et al*. (2018) [19] also reported increase in number of branches with foliar application of CCC in chrysanthemum. These results are also in close conformity with earlier findings of Rajyalakshmi and Rajsekhar (2014) [20] in marigold, Badge *et al*. (2017) [2] in annual chrysanthemum and Anuradha *et al*. (2017) [1] in marigold. The maximum plant spread (36.25 cm and 35.14 cm in N-S and E-W direction, respectively) was obtained with the application of 2000 ppm CCC (T_{16}). Significant improvement was noticed in plant spread after foliar application of plant growth regulators as compared to control. Maximum plant spread was noticed with higher concentration of plant growth retardant cycocel. Plant growth retardants are commonly used to retard the shoot length of the plant without inducing phytotoxic effects. Suppression of apical dominance by cycocel reduces plant height and induces the lateral vegetative bud growth (Cathey and Stuart, 1961) [4], which might have ultimately resulted in increased plant spread. These results corroborate the findings of Kudmate *et al*. (2016) [7] and Badge *et al*. (2017) [2] in annual chrysanthemum. The effect of foliar application of different plant growth regulators on number of suckers per plant was found non-significant. However, maximum number of suckers per plant (4.93) was recorded with the treatment T_{16} *i.e.* CCC @ 2000 ppm.

Flowering parameters

The observations on the different flowering parameters *viz*., days to first bud initiation, days to first flower opening, days to full bloom and number of flowers per plant were recorded and analyzed to evaluate the treatments (Table 1). Among all the treatments, earliest bud appearance (58.07 days), first flower opening (83.73 days) and full blooming (100.67 days) was recorded with treatment T_4 (GA_3 @ 200 ppm) which was at par with treatment T_3 *i.e.* GA_3 @ 150 ppm for all these characters (60.13 days, 88.73 days, 102.13 days for bud appearance, first flower opening and full blooming, respectively).

Table 1: Effect of plant growth regulators on growth and flowering parameters of chrysanthemum

Notation	Treatments	Plant height 60 DAT (cm)	Plant height 90 DAT (cm)	Number of branches per plant	Plant spread N-S (cm)	Plant spread E-W (cm)	Number of suckers per plant	Days to first bud initiation	Days to first flower opening	Days to full bloom	Number of flowers per plant
T_1	Control (water spray)	20.83	42.64	3.27	22.37	21.26	4.74	78.27	104.33	121.07	56.60
T_2	GA_3 100 ppm	28.85	57.71	6.37	29.82	28.69	5.00	63.60	91.27	107.13	76.67
T_3	GA_3 150 ppm	29.58	58.77	6.53	31.24	30.07	4.53	60.13	88.73	102.13	80.47
T_4	GA_3 200 ppm	32.51	63.37	6.73	32.17	31.01	4.67	58.07	83.73	100.67	81.53
T_5	NAA 100 ppm	25.04	51.47	4.27	26.10	24.94	4.42	69.07	96.13	114.00	70.27
T_6	NAA 150 ppm	25.56	53.37	4.53	26.24	25.12	4.60	68.00	95.53	113.13	71.13
T_7	NAA 200 ppm	26.06	53.96	4.80	27.11	26.00	4.96	67.40	95.00	112.60	73.27
T_8	Triacontanol 10 ppm	22.91	48.91	3.40	23.70	22.56	4.95	76.93	103.20	120.13	62.73
T_9	Triacontanol 20 ppm	24.41	50.44	4.00	25.75	24.61	4.45	74.20	101.87	119.20	63.67
T_{10}	Triacontanol 30 ppm	25.17	51.44	4.20	26.12	25.00	4.95	73.67	100.07	117.67	67.00
T_{11}	SA 100 ppm	28.45	57.03	6.00	29.71	28.57	4.61	66.53	91.47	110.00	76.00
T_{12}	SA 150 ppm	27.72	56.69	5.87	28.64	27.50	4.97	67.00	93.00	111.20	75.60
T_{13}	SA 200 ppm	26.11	54.76	5.73	27.42	26.25	4.94	68.13	94.07	112.07	73.80
T_{14}	CCC 500 ppm	22.51	47.53	7.02	32.63	31.51	4.27	72.93	99.53	117.00	81.87
T_{15}	CCC 1000 ppm	21.84	46.56	7.20	33.62	32.51	4.51	70.60	98.80	115.27	83.00
T_{16}	CCC 2000 ppm	21.04	44.24	8.07	36.25	35.14	4.92	69.53	96.93	114.13	87.60
S.Em. ±		0.82	1.54	0.17	0.86	0.87	0.22	1.85	1.93	2.22	1.42
C.D. at 5%		2.37	4.45	0.49	2.48	2.50	NS	5.35	5.57	6.40	4.11
C.V. (%)		5.57	5.09	5.40	5.19	5.44	5.38	4.65	3.49	3.40	3.34

Among various plant growth regulator treatments, the early bud initiation was recorded with the foliar application of GA_3. This may be due to the earlier shift to reproductive phase due to rapid completion of vegetative phase because of increase in endogenous level of GA_3. The gibberellins reduce juvenile period of the plants because of its higher capacity of cell division and cell elongation, which causes early maturity in the plants (Lockhart, 1960) [11]. Moreover, with the termination of the juvenile phase, shoot apical meristem instead of producing leaves and branches starts producing buds. These results are in line with the findings of Mounika *et al*. (2019) [13] who observed minimum days to bud initiation with higher GA_3 concentration in chrysanthemum. These results also corroborate findings of Kumar *et al*. (2014) [8] in marigold. In contrast, significantly maximum number of flowers per plant (87.60) were recorded with the application of treatment T_{16} *i.e.* CCC @ 2000 ppm. The increase in number of flowers per plant with cycocel might be attributed to the development of large number of axillary shoots as a result of cessation of the terminal growth. Plants sprayed with growth retardants have built up sufficient food reserves due to reduction in plant height with increasing plant spread and number of branches which further resulted in higher production of photosynthates. The quick mobilization of these photosynthates from leaves (source) to flower (sink) might have increased number of flowers per plant. The results are in accordance with the findings of Rajyalakshmi and Rajsekhar (2014) [20] in marigold.

Yield parameters

The observations on the different yield attributing characters i.e. weight of flowers per plant, flower yield per plot and flower yield per hectare are presented in Table 2. Significantly maximum weight of flowers per plant (279.49 g) was recorded with treatment T_4 (GA_3 @ 200 ppm) followed by T_3 (GA_3 @ 150 ppm). This might be due to the reason that application of gibberellic acid induces cell elongation and cell division which reflected in longer petals and larger flower size and subsequently in higher weight of flowers per plant. Kumar *et al*. (2020) [9] also reported the maximum flower yield per plant with the increased concentration of GA_3 in marigold. Increase in weight of flowers per plant by GA_3 has earlier also been reported by Patel *et al*. (2010) [118] in chrysanthemum and Sharma and Joshi (2015) [21] in China aster.

Significantly maximum flower yield per plot and flower yield per hectare *i.e.* 2.38 kg and 293.27 q, respectively was obtained with the application of 200 ppm GA_3 (T_4). The increase in yield attributes might be due to the fact that gibberellic acid stimulated overall vegetative growth of plants facilitating more photosynthetic area and metabolic activities resulting in more transport and utilization of the photosynthetic product which ultimately resulted in higher flower yield. These results are also in same line with the earlier findings of Kudmate *et al*. (2016) [7] in annual chrysanthemum and Kalaimani *et al*. (2017) [6] in African marigold.

Quality parameters

The observations on the different quality parameters such as flower diameter and weight of individual flower influenced by various treatments. While, shelf life, chlorophyll ‘a’, ‘b’ and total chlorophyll content were found non-significant (Table 2). Among different treatments, significantly larger flower diameter (6.04 cm) was noted in treatment T_4 (GA_3 @ 200 ppm).

Table 2: Effect of plant growth regulators on yield and quality parameters of chrysanthemum variety 'Ratlam Selection'

Notation	Treatments	Weight of flowers per plant (g)	Flower yield per plot (kg)	Flower yield per ha (q)	Shelf life	Flower diameter (cm)	Weight of individual flower (g)	Chlorophyll 'a' content	Chlorophyll 'b' content	Total chlorophyll content	BCR
T_1	Control (water spray)	130.41	1.11	137.04	4.67	3.64	2.02	24.73	18.64	43.35	1.77
T_2	GA_3 100 ppm	231.53	1.98	243.90	4.69	5.61	3.08	26.96	20.31	47.26	3.12
T_3	GA_3 150 ppm	246.62	2.11	260.12	4.67	5.64	3.15	26.82	20.21	47.02	3.31
T_4	GA_3 200 ppm	279.49	2.38	293.27	5.14	6.04	3.40	27.56	20.77	48.31	3.70
T_5	NAA 100 ppm	189.65	1.52	187.37	4.86	5.09	2.78	26.12	19.68	45.79	2.42
T_6	NAA150 ppm	199.11	1.59	196.62	4.87	5.12	2.90	26.17	19.72	45.87	2.53
T_7	NAA 200 ppm	210.31	1.68	208.00	4.93	5.30	2.92	26.38	19.88	46.25	2.68
T_8	Triacontanol 10 ppm	144.50	1.16	142.73	4.80	3.96	2.13	25.16	18.96	44.11	1.84
T_9	Triacontanol 20 ppm	145.81	1.17	144.25	4.60	4.45	2.29	25.66	19.33	44.98	1.85
T_{10}	Triacontanol 30 ppm	147.52	1.18	145.66	4.99	4.50	2.48	26.13	19.69	45.81	1.86
T_{11}	SA 100 ppm	230.76	1.85	228.04	4.46	5.60	2.98	26.67	20.10	46.75	2.94
T_{12}	SA 150 ppm	230.01	1.84	227.14	4.88	5.56	2.99	26.65	20.08	46.72	2.93
T_{13}	SA 200 ppm	218.60	1.75	215.97	4.62	5.42	2.95	26.28	19.80	46.07	2.79
T_{14}	CCC 500 ppm	232.31	1.86	229.57	4.46	5.01	2.76	26.49	19.97	46.45	2.27
T_{15}	CCC 1000 ppm	235.89	1.89	233.06	4.87	4.72	2.70	26.34	19.85	46.18	1.87
T_{16}	CCC 2000 ppm	238.30	1.91	235.39	4.74	4.56	2.68	26.52	19.98	46.49	1.37
S.Em. ±		6.45	0.08	10.07	0.20	0.14	0.08	0.65	0.50	1.17	-
C.D. at 5%		18.64	0.24	29.09	NS	0.39	0.24	NS	NS	NS	-
C.V. (%)		5.40	8.38	8.38	7.36	4.72	5.25	4.26	4.33	4.40	-

Selling price **₹ 40** per kg loose flowers

It is evident from the results that GA_3 produced maximum flower diameter. The reason for enhancement of flower size and diameter might be due to the increase in length of petals. Greater diameter might also be due to better partitioning by photosynthates to reproductive sink under the control of GA_3. Similar findings have also been reported by Shinde *et al*. (2010) [23] in chrysanthemum and Kumar *et al*. (2020) [9] in African marigold. The maximum individual flower weight (3.40 g) was recorded in treatment T_4 (GA_3 @ 200 ppm). The weight of individual flower was significantly influenced with the application of plant growth regulators. The foliar application of GA_3 may be attributed to an increase in length of petals and pedicel accompanied by increased number of petals which further resulted in increase of individual flower weight. These results are in resemblance with the findings of Kumar *et al*. (2010) [10] who also recorded maximum individual flower weight with foliar application of GA_3 in African marigold. Similar findings have also been reported by Padampriya and Chezhiyan (2002) [17] in chrysanthemum and Kumar *et al*. (2020) [9] in marigold.

Economics
From the economic point of view, highest gross income (11, 73,080 ₹/ha), net income (8, 55,778 ₹/ha) and benefit cost ratio (3.70) was observed with the application of GA_3 @ 200 ppm as compared to other treatments.

Conclusions
Based on the results of the present investigation it can be concluded that foliar application of 200 ppm GA_3 is beneficial for obtaining better growth, maximum yield per hectare with good quality and economic returns in 'Ratlam Selection' variety of chrysanthemum.

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