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RESEARCH ARTICLE

Effects of Foliar Application of Plant Growth Regulators on Growth and Flowering Characteristics of Chrysanthemum CV. Paintball

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ABSTRACT

The study was conducted to evaluate the effect of various concentrations of gibberellic acid (GA_3) and cycocel (CCC) on growth and flowering characteristics of chrysanthemum cv. Paintball. There were three concentrations of GA_3 (100, 200, 300 ppm) and CCC (1000, 1500, 2000 ppm) along with control one. Data regarding growth and flowering characteristics indicated that both attributes were varied significantly ($P \leq 0.05$). Application of GA_3 @ 300 ppm exhibited maximum plant height (59.85 cm), plant spread (24.51 cm), number of branches per plant (18.67), number of suckers (9.33), number of leaves per plant (64.67), leaf area per plant (174.02 cm^2), plant fresh (333.59 g) and dry weight (39.94 g), number of flowers per plant (34.67), flower size (9.38 cm), flower persistence (45.67 days), flower fresh (6.18 g) and dry weight (1 g). However, plants treated with the same GA_3 concentration took minimum time to bloom (110.67 days). Moreover, GA_3 @ 200 ppm concentration also showed encouraging results regarding all above parameters. However, effects of CCC appeared as growth retardant, which delayed flowering time without affecting floral quality traits.

INTRODUCTION

Chrysanthemum (*Dendranthema morifolium*) was first cultivated in China back in the 15th century B.C as a flowering herb, which was introduced into the Western world during the 17th Century as an ornamental plant. It is widely grown for indoor and outdoor beautification, fragrance, clean air, and serenity. There are hundreds of chrysanthemum varieties, which are classified into eight different types such as single, pompom, cushion, anemone, spider, spoon, quill and decorative (Bircumshaw and Damp, 1992). The popularity of this ornamental has increased in the Kingdom of Saudi Arabia (KSA) not only due to its remarkable aesthetic beauty but also due to its good potential to grow as cut flowers. In KSA, the peak time of blooming of many varieties of chrysanthemum is December to January.

The world trade of ornamentals is over 100 billion USD, which is growing 15% per annum. Among ornamental plants, the demand of chrysanthemum in developed countries is more than 90% (Verma et al., 2014). Therefore, the growers involved in ornamental industry adopt various strategies to improve plant growth and flower quantity and quality such as application of organic and inorganic fertilizer, manipulation of plant environment including temperature, light duration, quality and quantity, and the use of plant growth regulators (PGRs). The latter approach has been used in floriculture industry since 1940 to control vegetative, reproductive and post-harvest developmental processes (Basra, 2000). It is predicted that the global PGRs market will surge from 3.5 billion USD (2014) to 6.4 billion USD by 2020 (Anonymous, 2016). PGRs such as auxins, gibberellins, cytokinins, abscisic acid, ethylene, brassinosteroids, salicylates, jasmonates etc. are also available in synthetic forms, which are commonly used in ornamental industry for nursery production, ornamental foliage plant and several other flowering crops (Arteca, 1996; Sanap et al., 2000). In present study, two PGRs were chosen, gibberellins (GA_3) and cycocel or chlormequat (CCC), the former one regulates the growth and developmental processes while the latter one has inhibitor properties. Few previous studies showed that maximum plant height, number of branches, leaf area, dry weight, number of seeds per flower and seed yield of chrysanthemum were obtained when treated with GA_3 @ 200 ppm (Sainath and Meena, 2012). However, Dorajeerao et al. (2012)

recorded highest number of flowers, flower yield per plot, plant height, leaf area and dry matter accumulation by the application of GA_3 @ 100 ppm, however, CCC had an opposite effect regarding these parameters as compared to GA_3 and control. Sharifuzzaman et al. (2011) reported that GA_3 treated plants showed significant increase in plant spread, leave number and leave length, higher number of sucker and flowers and CCC produced less. Sajid et al. (2016) observed that the application of GA_3 (250 $mg.L^{-1}$) significantly promoted plant height, leaves per plant, leaf area, number of branches and suckers, days to flowering and number of flowers per plant of cv. Fanfare. CCC negatively affected vegetative and floral characteristics of poinsettia (Renu and Ranjan, 2013) and hybrid lily (Naji et al., 2015). Keeping in view the importance and wide application of PGRs in floricultural industry, present study was aimed to determine the significance of GA_3 and CCC in chrysanthemum to improve its vegetative and floral quality characters under the climatic conditions of Al-Ahsa, Saudi Arabia.

MATERIALS AND METHODS

The present study was conducted to determine the effect of GA_3 and CCC on growth and flowering of chrysanthemum cv. Paintball under glasshouse conditions at Agricultural Research and Veterinary Experimental Station, King Faisal University, Al-Ahsa, Saudi Arabia during year 2014-15. The experiment was laid out on completely randomized design with seven treatments comprising of three levels of GA_3 at 100, 200 and 300 ppm, and CCC at 1000, 1500 and 2000 ppm along with control. There were six replicates in each treatment.

Rooted terminal cuttings of cv. Paintball were taken from the well established mother plants and were planted in 9 cm plastic pots separately on 15th August. After one month, they were transplanted in 25 cm pots having a mixture of leaf compost and sand at 2:1 ratio. A uniform dose (2.5 g pot^{-1}) of 20:20:20 NPK fertilizer was also applied ten days after transplantation. Different concentrations of GA_3 (@ 100, 200 and 300 ppm) and CCC (@1000, 1500 and 2000 ppm) solutions were foliar sprayed on plants at 7 am in the morning on 25^{th} and 50^{th} day after transplanting (twice), whereas distilled water was sprayed on control plants. Attention was given to pot spacing in order to reduce plant competition (shade avoidance). Due to organic nature of soil mixtures, weeds were rooted out by hand whenever emerged. All other cultural practices were uniformly followed for all the treatments. The growth and flowering parameters studied were: plant height, plant spread, number of branches per plant, number of suckers per plant, number of leaves per plant, leaf area per plant, plant fresh and dry weight, days to flower opening, number of flowers per plant, flower size, flower persistence, flower fresh and dry weight. All means and standard errors were calculated using MS-Excel 2010 software. However, data analysis software Statistix-10 (Analytical Software, Tallahassee, FL, USA) was used to calculate standard errors of differences between means and ANOVA.

RESULTS AND DISCUSSION

Data in Table 1 indicated significant ($P \leq 0.05$) differences regarding the plant height, plant spread, number of branches per plant, number of suckers per plant, number of leaves per plant, leaf area per plant, plant fresh and dry weight of chrysanthemum cv. Paintball treated with different GA_3 and CCC concentrations. Plants attained maximum height (59.85 cm) when treated with GA_3 @ 300 ppm followed by that of 200 (55.71 cm) and 100 ppm (52.37 cm) concentrations. CCC worked as growth retardant and its higher concentration (2000 ppm) significantly reduced plant height up to 44.19 cm followed by that of 1500 (46.88 cm) and 1000 ppm (48.37 cm) concentration. Plants grown in control were 50.83 cm tall. A similar trend was observed regarding the plant spread parameter where maximum plant spread (24.51 cm) was observed when GA_3 @ 300 ppm was applied followed by that of 200 (22.85 cm) and 100 ppm (21.12 cm) concentrations. Plants in control treatment spread 20.40 cm. CCC @ 2000 ppm significantly reduced plant canopy i.e. 17.19 cm followed by that of 1500 (18.49 cm) and 1000 ppm (19.25 cm) concentrations. Plant height is influenced by different factors such as temperature (Munir et al., 2004a), light (Munir et al., 2004b) and PGRs (Baloch et al., 2013). Foliar application of GA_3 might have influenced the stem elongation and canopy spread by stimulating cell division and elongation. These findings are in line with those of Sajid et al. (2016), Patel et al. (2010), Schmidt et al. (2003) and Talukdar and Paswan (1994) who observed an increase in plant height with the increased GA_3 concentrations in chrysanthemum. On the other hand, CCC, being a gibberellin inhibitor, reduced plant height and spread as compared to plants treated with GA_3 and in control, which is also reported in chrysanthemum (Patel et al., 2010; Vaghasia and Polara, 2015) and *Erysimum marshallii* (Bhat et al., 2011). Comparing the effect of two PGRs on number of branches per plant, a non-significant effect of both PGRs was observed, however, it was significantly different when compared with control treatment. Maximum number of branches per plant (18.67) was counted in GA_3 @ 300 ppm treatment followed by those of CCC @ 2000 ppm (17.33), GA_3 @ 200 ppm and CCC @ 1500 ppm (16.67), CCC @ 1000 ppm (15.67) and GA_3 @ 100 ppm (14.33) concentrations.

Table 1: Effect of different concentrations of GA_3 and Cycocel on plant growth characteristics of chrysanthemum cv. Paintball

Treatments	Plant height (cm)	Plant spread (cm)	No. of branches per plant	No. of leaves per plant	Leaf area per plant (cm^2)	No. of suckers per plant	Plant fresh weight (g)	Plant dry weight (g)
Control	50.83(±1.17)	20.40(±0.83)	10.33(±1.45)	34.67(±0.88)	93.35(±2.34)	5.33(±0.33)	264.04(±4.81)	24.72(±2.77)
GA_3 @ 100 ppm	52.37(±1.42)	21.12(±0.48)	14.33(±1.45)	43.67(±1.86)	117.73(±5.07)	7.00(±1.00)	281.74(±10.22)	30.22(±3.53)
GA_3 @ 200 ppm	55.71(±2.37)	22.85(±1.15)	16.67(±2.19)	54.33(±2.34)	146.26(±6.33)	9.00(±0.58)	300.34(±31.84)	36.22(±5.10)
GA_3 @ 300 ppm	59.85(±2.62)	24.51(±1.33)	18.67(±2.03)	64.67(±2.61)	174.02(±7.01)	9.33(±0.67)	333.59(±8.30)	39.94(±1.00)
Cycocel @ 1000 ppm	48.37(±1.49)	19.25(±0.72)	15.67(±1.45)	34.67(±2.61)	93.25(±7.01)	6.67(±0.88)	271.51(±9.10)	27.53(±1.70)
Cycocel @ 1500 ppm	46.88(±2.41)	18.49(±1.33)	16.67(±1.45)	27.33(±2.03)	73.53(±5.46)	5.67(±0.33)	277.83(±11.65)	29.56(±0.55)
Cycocel @ 2000 ppm	44.19(±0.42)	17.19(±0.42)	17.33(±1.20)	23.67(±0.88)	63.66(±2.38)	5.00(±0.58)	282.76(±13.53)	31.10(±1.49)
$SED_{(0.05)}$	2.80	1.41	2.47	2.96	7.99	1.01	23.13	4.14
$LSD_{(0.05)}$	6.10*	3.07*	5.39*	6.46**	17.40**	2.20*	50.40*	9.03*

Data in parenthesis indicated standard errors within replicates. SED stands for standard error of difference among means. LSD stands for least significant difference among means. SED and LSD are calculated at 5% level of probability. * and ** indicated significant and highly significant statistical difference among treatments respectively.

Plants in control treatment produced minimum number of branches per plant (10.33). The possible reason could be that the foliar application of GA_3 might influenced the vegetative growth by encouraging cell division and elongation that increased branch numbers. However, CCC had opposite effect on branching. These findings are in agreement with those of Sajid et al. (2016) and Sainath and Meena (2012), who recorded more number of branches with increased concentration of GA_3 in chrysanthemum, however, CCC reduced branching numbers as compared to GA_3 and control treatments.

Table 1 also showed that leaf numbers per plant were higher when plants were treated with different concentrations of GA_3 such as @ 300 (64.67), 200 (54.33) and 100 ppm (43.67). Plants in control treatment produced same number of leaves as were in CCC @ 1000 ppm treated plants i.e. 34.67 leaves per plant followed by those of CCC @ 1500 (27.33) and 2000 ppm (23.67) treated plants. Greater leaf numbers were recorded at higher concentration of GA_3, which might increase cell division, cell elongation and tissue differentiation that resulted in the initiation of more number of leaves. Moreover, the increased number of branches might be attributed to improve leaf initiation. The response of CCC was antagonistic to GA_3. These findings are at par with those of Sajid et al. (2016), Sainath and Meena (2012), and Sharifuzzaman et al. (2011). Similar trend was observed regarding leaf area per plant characteristic i.e. maximum leaf area was estimated when GA_3 @ 300 (174.02 cm^2), 200 (146.26 cm^2) and 100 ppm (117.73 cm^2) was applied. Plants in control or treated with CCC @ 1000 ppm resulted in 93.35 and 93.25 cm^2 leaf area followed by those of CCC @ 1500 (73.53 cm^2) and 2000 ppm (63.66 cm^2) concentrations. Chrysanthemum plants exhibited a significant increase in leaf area when GA_3 was applied that in fact stimulates the cell division and elongation, which ultimately increased the leaf area whereas CCC suppressed the cell physiology which resulted in smaller leaf area. Similar results were reported by Dorajeerao et al. (2012), Sainath and Meena (2012) and Sharifuzzaman et al. (2011) when chrysanthemum plants were treated with GA_3 and CCC.

Data regarding number of suckers per plants indicated that the GA_3 concentrations @ 300 and 200 ppm behaved alike and produced highest number of suckers i.e. 9.33 and 9, respectively followed by those of GA_3 @ 100 ppm (7) and CCC @ 1000 ppm (6.67). Plants treated with CCC @ 1500 and 2000 ppm produced 5.67 and 5 suckers, respectively which was closely followed by that of control treatment i.e. 5.33 suckers. Number of suckers increased with the increase in GA_3 concentration while CCC behaved inversely. It showed that GA_3 might attributed to the increase in branch numbers, leaf and leaf area, which eventually enhanced the translocation of photosynthates to the roots to produce higher number of suckers. These findings are in agreement with the findings of Sajid et al. (2016) and Sharifuzzaman et al. (2011) who observed an increase in suckers with GA_3 application in chrysanthemum. Application of GA_3 @ 300 and 200 ppm significantly increased plant fresh weight i.e. 333.59 and 300.34 g, respectively, whereas CCC @ 2000 (282.76 g), GA_3 @ 100 (281.74 g), CCC @ 1500 (277.83 g) and 1000 ppm (271.51 g) treatments were statistically at par. Minimum plant fresh weight (264.04 g) was measured in control treatment. Similarly, maximum plant dry weight was recorded in plants which received GA_3 concentrations @ 300 (39.94 g) and 200 ppm (36.22 g). All other treatments were statistically at par to one another including control. However, plants treated with CCC @ 2000 ppm produced 31.10 g plant dry weight followed by those of GA_3 @ 100 ppm (30.22 g), CCC @ 1500 (29.56 g) 1000 ppm (27.53 g), and control (24.72 g). Gibberellins are engaged in regulation of many phases during plant development of which the most recognizable function is to promote cell division that leads to stem elongation, canopy spread, branchial plant with increased leaf number and area whereas cycocel adversely affect these characteristics. Similar response of both PGRs was observed in present study, which affect plant fresh and dry biomass. Higher concentration of GA3 increased plant fresh and dry weight as compared to its lower concentrations and CCC application. Dorajeerao et al. (2012) reported that above ground dry matter accumulation increased with increased concentration of GA_3 whereas as CCC had opposite effect. Vaghasia and Polara (2015) stated that fresh and dry weight of chrysanthemum cv. IIHR-6 was negatively affected by CCC concentrations.

Floral characteristics data in Table 2 depicted that days taken to flowering, number of flowers per plant, flower size, flower persistence time, flower fresh and dry weight of chrysanthemum cv. Paintball was significantly ($P \leq 0.05$) influenced by different concentrations of GA_3 and CCC. Flowering time was minimum when plants were treated with GA_3 @ 300 (110.67 days), 200 (116.33 days) and 100 ppm (120.33 days). First two higher GA_3 concentrations were statistically at par. However, there was non-significant difference among rest of all treatments i.e. plants in control took 126.33 days to flower followed by CCC @ 1000 (127.67 days), 1500 (128.67 days) and 2000 ppm (129.33 days) concentrations. Three pathways to floral initiation was reported by Bradley et al. (1996) which are photoperiod (Munir et al., 2010; Baloch et al., 2011), temperature (Munir et al., 2004a) and GA_3 (Mutasa-Göttgens and Hedden, 2009). Present results indicated that application of GA_3 might enhanced floral initiation in chrysanthemum. The antagonistic role of ABA on GA_3 expression is reported in Barley (Gómez-Cadenas et al., 2001), however, Phengphachanh et al. (2012) reported that the GA_3 decreased the concentration of abscisic acid in plant shoot, which might enhance flower initiation and early flowering. Moreover, as the leaf numbers were increased in present study, which improved photosynthetic activity to enhance early flowering. These findings are confirming to those reported by Sajid et al. (2016), Sharifuzzaman et al. (2011), Patel et al. (2010) and Vaghasia and Polara (2015) who observed that plant treated with GA_3 took minimum time to flower while CCC prolonged flowering time. Data regarding number of flowers per plant showed that plants treated with GA_3 @ 300 (34.67), 200 (30.67) and 100 ppm (24.67) concentrations produced maximum flowers per plant, however, the 100 ppm GA_3 treatment was statistically different to the other two treatments. There was no significant difference found between other treatments, nevertheless, plants treated with CCC @ 2000, 1500, 1000 along with control bloomed 22, 21.33, 19.67 and 19.33 flowers per plant, respectively. The increase in flower numbers by GA_3 might be due to increase in leaf numbers and leaf area, which might have boosted the production and accumulation of assimilates that were translocated from source to sink for flowers production (Carvalho et al., 2006). These results are confirmed by those reported by Sajid et al. (2016), Dorajeerao et al. (2012), and Sainath and Meena (2012) who counted highest flowers numbers with increased GA_3 application. Flower number was decreased by CCC application, however, it was slightly higher when compared to control. Vaghasia and Polara (2015) reported similar results when compared CCC treatments with control, however, Tabora and Hampton (1992) reported that CCC treatments did not clearly indicate any increase in flower numbers in lotus.

Maximum sized flower were produced by plants sprayed with GA_3 @ 300 (9.38 cm) and 200 ppm (8.53 cm) concentrations. However, GA_3 @ 200 ppm concentration was statistically non-significant with GA_3 @ 100 (7.70 cm), CCC @ 1500 (7.40 cm) and 2000 ppm (7.86 cm) concentrations. Minimum flower size (4.81 cm) was observed in control plants. The increase in the flower size might be due to the increase in leaf numbers and leaf area, which lead to produced more

Table 2: Effect of different concentrations of GA_3 and Cycocel on flowering characteristics of chrysanthemum cv. Paintball

Treatments	Day to flower opening	No. of flowers per plant	Flower size (cm)	Flower persistence (days)	Flower fresh weight (g)	Flower dry weight (g)
Control	126.33(±2.34)	19.33(±0.67)	4.81(±0.64)	35.33(±1.45)	3.77(±0.12)	0.67(±0.05)
GA_3 @ 100 ppm	120.33(±1.45)	24.67(±4.67)	7.70(±0.41)	38.67(±2.03)	5.28(±0.13)	0.90(±0.03)
GA_3 @ 200 ppm	116.33(±2.03)	30.67(±0.67)	8.53(±0.48)	42.00(±1.16)	5.55(±0.20)	0.95(±0.03)
GA_3 @ 300 ppm	110.67(±2.91)	34.67(±3.72)	9.38(±0.41)	45.67(±1.20)	6.18(±0.11)	1.00(±0.00)
Cycocel @ 1000 ppm	127.67(±1.77)	19.67(±2.03)	6.98(±0.21)	35.67(±1.77)	5.43(±0.20)	0.90(±0.03)
Cycocel @ 1500 ppm	128.67(±0.88)	21.33(±1.77)	7.40(±0.57)	38.67(±2.03)	4.78(±0.29)	0.85(±0.03)
Cycocel @ 2000 ppm	129.33(±1.45)	22.00(±1.53)	7.86(±0.34)	42.00(±1.16)	4.81(±0.19)	0.82(±0.03)
$SED_{(0.05)}$	2.89	3.80	0.68	1.77	0.27	0.05
$LSD_{(0.05)}$	6.30**	8.28*	1.47**	3.86**	0.58**	0.10**

Data in parenthesis indicated standard errors within replicates. SED stands for standard error of difference among means. LSD stands for least significant difference among means. SED and LSD are calculated at 5% level of probability. * and ** indicated significant and highly significant statistical difference among treatments respectively.

photosynthates. These results are in agreement with those of Sajid et al. (2016), Sainath and Meena (2012) and Patel et al. (2010) who reported that flower size was increased by the application of GA_3 as compared to CCC concentration. Similarly, maximum number of days to flower persistence (45.67) was counted when plants sprayed with GA_3 @ 300 followed by GA_3 @ 200 ppm and CCC @ 2000 ppm (42 days each). GA_3 concentration @ 100 ppm and CCC @ 1500 ppm behaved alike i.e. 38.67 days. Minimum number of days to flower persistence was recorded in control (35.33 days) and CCC @ 1000 ppm (35.67 days) concentration. Similar findings were observed by Sajid et al. (2016) and Patel et al. (2010) by the application of GA_3. However, Vaghasia and Polara (2015) stated that flower persistence was slightly higher in CCC treatments as compared with control plant. Table 2 also indicated that flower fresh weight was higher (6.18 g) when GA_3 @ 300 was applied. Treatments GA_3 @ 200 (5.55 g), GA_3 @ 100 (5.28 g) and CCC @ 1000 ppm (5.43 g) statistically behaved alike whereas plants in control had 3.77 g flower weight. Similar trend was noted regarding flower dry weight data i.e. 1 g flower dry weight was obtained when GA_3 @ 300 ppm was applied followed by that of GA_3 @ 200 ppm treatment (0.95 g). GA_3 @ 100 (0.90 g), CCC @ 1000 (0.90 g) and 1500 ppm (0.85 g) were statistically at par whereas dry weight of flower produced by control plants was 0.67 g. These results indicated that GA_3 concentrations increased the fresh and dry flower weight, which mean that GA_3 enhanced the accumulation of assimilates that were diverted and stored during flower formation. These results coincide with those reported by Sajid et al. (2016), Vaghasia and Polara (2015), Sainath and Meena (2012) and Patel et al. (2010) who reported that GA_3 flower weight was increased when GA3 was applied as compared to CCC treatments.

Conclusion

Among various gibberellic acid and cycocel concentrations, GA_3 @ 300 ppm was superior regarding all growth and flowering parameters and reduce the time to flowering by 16 days for early bloom. Furthermore, GA_3 @ 200 ppm concentration also showed better results and stood as the second best treatment. The possible use of cycocel emerged as growth retardant, which also delayed flowering time up to 19 days without any expense to other floral quality characteristics.

Authors' contributions

All authors contributed equally in finalizing this manuscript.

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