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INFLUENCE OF FOLIAR APPLICATION OF GROWTH REGULATORS ON VEGETATIVE GROWTH AND FLOWERING OF CHRYSANTHEMUM

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Abstract

The pot experiment was conducted at the Floriculture field of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during August 2020 to May 2021 to evaluate the foliar spray of gibberellic acid (GA_3), benzyl adenine (BA) and naphthalene acetic acid (NAA) on growth and flowering traits of chrysanthemum (*Chrysanthemum morifolium*). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Four weeks old seedlings of chrysanthemum genotype CM-019 (flower class: Pompon and flower colour: Orange yellow) were transplanted in pot keeping under natural sunlight. The aqueous solution of GA_3, BA and NAA @ 100 and 200 ppm of each were sprayed on the flower plants at monthly interval starting after one month of transplantation of seedlings along with control (water). The results revealed that vegetative growth and flowering parameters were significantly influenced by plant growth regulators. Maximum number of leaves per plant (50.0) and leaf area per plant (7.5 cm^2) were recorded from the spraying of BA @ 100 ppm closely followed by BA @ 200 ppm (48.0 and 7.0 cm^2/plant) and GA_3 @ 100 ppm only for number of leaves (47.0/plant). Spraying of GA_3 @ 100 ppm produced the tallest plant (70.0 cm) and the highest plant spread (23.0 cm). Number of flowers (26.0/plant), flower size (7.8 cm), average weight of stalk (37.0 g) and vase life (15.0 days) were also found maximum from the application of GA_3 @ 100 ppm, closely followed by GA_3 @ 200 ppm (23.5/plant, 7.2 cm, 36.0 g, 14.0 days) and NAA @ 100 ppm (18.5/plant, 7.0 cm, 36.0 g, 13.0 days) and irrespective of concentrations, BA failed to improve these characters. GA_3 @ 100 ppm recorded maximum length of stalk (37.5 cm) and rachis (29.0 cm), which was identical with GA_3 @ 200 ppm (34.6 cm and 25.0 cm), and BA @ 100 ppm gave the lowest length of stalk and rachis. GA_3 also caused faster initiation of flowering, whereas NAA and BA delayed it. GA_3 @ 100 ppm took the minimum days to flowering (50.0 days) was observed when plants were sprayed with GA_3 @ 100 ppm whereas it was maximum (69 days) from BA @ 100 ppm treatment. It can be concluded that GA_3 @ 100 ppm provided the best results for obtaining better vegetative growth of plants, maximum number of cut blooms with longer stalk as well as bigger flower size with prolonged vase life in chrysanthemum.

Keywords: Chrysanthemum, GA_3, BA, NAA, Phenology, Vase life.

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Introduction

Chrysanthemum (*Chrysanthemum morifolium* Ramat.) belongs to the family *Asteraceae* and is a very popular commercial flower grown for as cut flowers for vases, as loose flowers for garland making, general decoration, hair adornments, religious functions and interior decorations at ceremonies, as well as pot plants all over the world including Bangladesh. Chrysanthemums are native to East Asia and northeastern Europe and most of the species originate from East Asia and the center of diversity is in China (Liu *et al.,* 2012). There are more than 5000 different varieties with different names, grown all around the world. In some countries, it ranks next to rose in value of the crop produced. The agro-ecological conditions of the country are favorable for the culture and survival of chrysanthemum. For this, the flower growers of Bangladesh are very much interested in cultivating chrysanthemum instead of the traditional flower crops that usually do not give much return to them. As a result, recently chrysanthemum is becoming attractive to the growers as well as users, as it has great potential for local and export market.

Plant Growth Regulators (PGRs) such as auxins, gibberellins, cytokinins, abscisic acid, ethylene, brassinosteroids, salicylates, jasmonates etc. are 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). Gibberellic acid (GA_3) is a well-recognized synthetic gibberellins, which has been used for desirable plant growth, flower size, flower number and flower induction in many herbaceous flower crops. The flowering habit of long day or long short day plant can be controlled by regulating the endogenous level of gibberellins-like substances through the use of such growth promoter. The beneficial effects of GA_3 on growth and flowering has been reported in chrysanthemum (Patel *et al*., 2010; Alhajhoj, 2017; Aparna *et al*., 2018; Sajid *et al*., 2018; Farag *et al*., 2018; Sing and Bala, 2018; Singh *et al.,* 2018), in calendula (Khudus *et al*., 2017) and in china aster (Mishra *et al*., 2018). Naphthalene acetic acid (NAA) is a syntheticauxins, which has various physiological roles viz., encouraging cell division and cell enlargement. This PGR can enter into plants through leaves, branches and tender skin etc. and can influence plant growth, flowering and other properties. The beneficial effects of NAA on growth and flowering has been reported in chrysanthemum (Sahu *et al.*, 2021) and in calendula (Khudus *et al.,* 2017). Benzyl adenine has recently been used as one of other sources that can maintain or increase the quality of various ornamental plants (Buban, 2000; Han, 2001) and on many other physiological and developmental processes, including leaf senescence, leaf chlorosis, increase the vase life, delaying senescence of cut carnation by inhibiting ethylene biosynthesis (Cook *et al*., 1985), nutrient mobilization, apical dominance, the formation and activity of shoot apical meristems, floral development, combating drought stress in plants (Waterland *et al*., 2010). El-Ghait *et al*. (2018) recorded

increased plant height and highest number of branches and leaves per plant, number of flowers per plant and maximum vase life in chrysanthemum from the application of Kinetin (a synthetic cytokinin) @ 75 ppm. Singh and Bala (2018) obtained maximum vase life in chrysanthemum from the application of BA @ 200 ppm. Nambiar *et al*. (2012) reported that application of Benzyl adenine @ 200 ppm on dendrobium orchid were found to increase maximum inflorescence%, hastens inflorescence emergence, inflorescence size (length x width), number of leaves per plant, number of flowers per inflorescence and flower size. Application of proper doses of plant growth regulators may not only ensure better yield and quality of chrysanthemum, as well as minimize the wastage of growth regulators and cost. In Bangladesh, a few studies were done regarding the use of plant growth regulators, especially plant growth retardants for growth and flowering of chrysanthemum. The present study was, therefore, conducted to find out the optimum concentration of GA_3, BA and NAA to improve vegetative growth and flowering traits of chrysanthemum.

Material and Methods

The experiment was conducted at the field of Landscape, Ornamental and Floriculture Division of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during August 2020 to May 2021. Four weeks old seedling of chrysanthemum (CM-019) were collected from HRC, BARI and transplanted in 10 x 12 cm earthen pot in the month of October 2020. The pompon type genotype (CM-019) was used . The pots were filled with a mixture of media that consists of one part coarse sand, one part garden soil, one part cocodust, one part cowdung, a quarter part of wood ashes and two table spoonful's of bone meal. Subsequently, 10 g TSP, 6 g MoP, 0.10 g B as solubor (%) per pot were applied. Urea @ 2, 3 and 2 g per pot was applied at 30, 50 and 70 days after transplanting, respectively. The pots were kept under natural sunlight and distance were maintained 6 cm apart from one pot to another pot. The experiment was laid out in Randomized Completely Block Design (RCBD) with 5 replications (one pot considered as one replication). The experiment consists of 7 treatments viz. BA, GA_3 and NAA @ 100 ppm and 200 ppm of each and control. The growth regulators were sprayed on plants in the morning at monthly interval starting after one month of seedling transplantation. Control treated plants were sprayed with water. All the cultural operations such as weeding, mulching, watering, disbudding, pinching, staking etc. were done as per the need of the crop. Ridomyl Gold (a.i. Metalaxyl & Mancozeb) was sprayed on the plants @ 2.0 g/L H_2O thrice at 15 days interval starting from 20 days after transplanting as protective measures against the incidence of diseases such as leaf spot and powdery mildew. Ripcord (a.i. Cypermethryn) was also sprayed on the plants @ 2.0 ml/L H_2O thrice at 15 days interval starting from 30 days after transplanting as protective measures against the attack of insects such as aphids, thrips, leaf miners etc.

The data were recorded on plant height, number of leaves per plant, plant spread, leaf area per plant, days to flower initiation, number of flowers per pot, stalk length, rachis length, flower size, average weight of stalk after maturity indices of chrysanthemum flower. For observing post-harvest life of the cut flowers of chrysanthemum, GA_3, BA and NAA treated and untreated cut stems were collected from the field in the morning to avoid excessive heat and brought to the laboratory in a bucket containing 3-4 liters of water. Before placing cut stems in the vase water, stems were cut (slanting) to a uniform length of 25 cm and leaves near the bottom of the cut stems were removed except for few leaves below the inflorescence. Cut stems were placed in 250 ml conical flasks containing 200 ml of distilled water and kept in laboratory conditions at a room temperature of 18±2ºC and relative humidity of 70±5% under continuous illumination of florescence light. Five flowers were taken randomly and vase life was recorded from all the treatments by counting number of days from the time, when the cut flowers lose their decorative value after complete opening or shedding of petals. The recorded data were statistically analyzed with the help of computer base MSTAT software and treatment means were separated by Duncan's Multiple Range Test (DMRT) at 1% level of probability.

Results and Discussion

Vegetative growth parameters

Plant height

The tallest plant (70.0 cm) was recorded from the treatment GA_3 @ 100 ppm, whereas the minimum plant height (52.0 cm) from BA @ 100 ppm which was closely followed by that of BA @ 200 ppm (55.0 cm) (Table 1). Patel *et al*. (2010), Singh *et al*. (2018) and Sharifuzzaman *et al.* (2011) obtained the tallest plant from GA_3 @ 150 ppm in chrysanthemum. On the other hand, Farag *et al.* (2018) and Sahu *et al.* (2021) were obtained the tallest plant from GA_3 @ 200 ppm in chrysanthemum. Aparna *et al.* (2018), Alhajhoz (2017) and Sajid *et al.* (2018) was obtained highest plant height when the chrysanthemum plants treated with GA_3 @ 400 ppm, GA_3 @ 300 ppm and GA_3 @ 250 ppm, respectively. Talukder and Paswan (1998) was also obtained maximum value for this same trait from the spraying of GA_3 @ 40 ppm. Foliar application of GA_3 at a proper concentration might have influenced plant height by stimulating cell division and elongation at internodal region, which resulted in more number of cells and increase in cell length. The shortest plant height with application of BA might be due to counteracting the apical dominance.

Number of leaves per plant

The maximum number of leaves (50.0) per plant was recorded from BA @ 100 ppm, which was identical with BA @ 200 ppm (48.0/plant) and GA_3 @

100 ppm (47.0/plant), whereas the minimum number of leaves per plant (39.0) from control. The maximum number of leaves per plant with application of BA @ 100 ppm might be due to higher number of suckers per plant. Sahu *et al.* (2021), El-Ghait *et al.* (2018) and Sajid *et al.* (2018) also reported that maximum number of leaves per plant was observed from the plants sprayed with treatment containing GA_3 @ 200 ppm, GA_3 300 ppm and GA_3 @ 100 ppm, respectively. Aparna *et al*. (2018) reported that the result of higher number of leaves per plant might be due to GA_3 application at a proper concentration enhanced biosynthesis of protein and carbohydrates leading to enhancement of initiation of leaf primordial growth and consequently production of more leaves.

Table 1. Effect of BA, GA_3 and NAA on vegetative growth parameters of chrysanthemum

Growth regulators (ppm)	Plant height (cm)	Number of leaves/ plant	Leaf area (cm^2)/plant	Plant spread (cm)
BA @ 100 ppm	52.0 d	50.0 a	7.5 a	14.9 bc
BA @ 200 ppm	55.0 cd	48.0 ab	7.0 ab	14.4 bc
GA_3 @ 100 ppm	70.0 a	47.0 ab	6.4 bc	23.0 a
GA_3 @ 200 ppm	65.0 b	44.8 b	6.0 bc	20.0 ab
NAA @ 100 ppm	63.0 bc	42.3 bc	5.9 bc	17.0 b
NAA @ 200 ppm	61.0 bc	42.0 bc	5.8 bc	15.0 bc
Control	58.0 c	39.0 c	5.5 c	12.0 c
CV (%)	8.7	7.5	9.5	9.2

In a column mean values with common letters do not differ significantly at 1% level of probability by DMRT.

Leaf area per plant

The maximum leaf area per plant (7.5 cm^2) was recorded from BA @ 100 ppm closely followed by that of BA @ 200 ppm (7.0 cm^2/plant), whereas, the minimum leaf area per plant (5.5 cm^2) in control. This might be due to production of higher number of leaves per plant, when plants are treated with benzyl adenine at a specific concentration. On the contrary, Farag *et al.* (2018) obtained maximum leaf area per plant through application of GA_3 @ 200 ppm, closely followed by GA_3 @ 100 ppm, though they obtained increased leaf area per plant from BA @ 200 and 100 ppm compared to control. These results of GA_3 might be attributed to the role of gibberellic acid at a proper concentration on stimulation of cell division and cell elongation of the leaves or on increasing

the number of leaves per plant, or all of them, consequently the leaf area per Chrysanthemum plant could be increased reported by Farag *et al.*, (2018).

Plant spread

The maximum plant spread (23.0 cm) was noticed in GA_3 @ 100 ppm which was statistically similar to GA_3 @ 200 ppm (20.0 cm) and the minimum plant spread (12.0) in control (Table 1). Singh *et al.* (2018) and Patel *et al.* (2010) also obtained maximum plant spread in chrysanthemum from GA_3 @ 150 ppm closely followed by GA_3 @ 100 ppm among three GA_3 concentrations (50, 100 and 150 ppm). Alhajhoj (2017) reported that application of GA_3 @ 300 ppm produced maximum plant spread in chrysanthemum. Sahu *et al*. (2021) reported that maximum spread of plant was noticed from the chrysanthemum plants sprayed with treatment containing GA_3 @ 200 ppm. Patel *et al.* (2010) explained that higher plant spread might be due to GA_3 which enhanced cell division and cell enlargement, promotion of protein synthesis coupled with dry matter accumulation.

Flowering parameters

Days to flower initiation

There was a significant difference in days to flowering among the different treatments. The minimum days (50) required for flower initiation was observed in GA_3 @ 100 ppm which was closely followed by GA_3 @ 200 ppm (52 days) (Fig. 1). Application of BA @ 100 ppm took maximum days (69) to initiate flowers followed by control (66 days) and BA @ 200 ppm (64 days). Application of NAA @ 100 ppm took 58 days required for flower imitation followed by NAA @ 200 ppm (56 days). Singh *et al*. (2018) also reported that minimum number of days required for first flower bud appearance was recorded with 100 ppm concentration of GA_3 in chrysanthemum. It is evident that GA_3 @ 100 ppm and GA_3 @ 200 ppm reduced time to initiate flower by 16 and 14 days, respectively for early bloom compared to control. Irrespective of concentrations, NAA also took less time to initiate flower compared to control, but BA @ 100 ppm took more time to initiate flower compared to control, whereas BA @ 200 ppm reduced time only by two days compared to control. 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 confirmed by those reported by Sajid *et al*., (2018), Sharifuzzaman *et al*. (2011) and Patel *et al*. (2010) who observed that plant treated with GA_3 took minimum time to initiate flower in chrysanthemum.

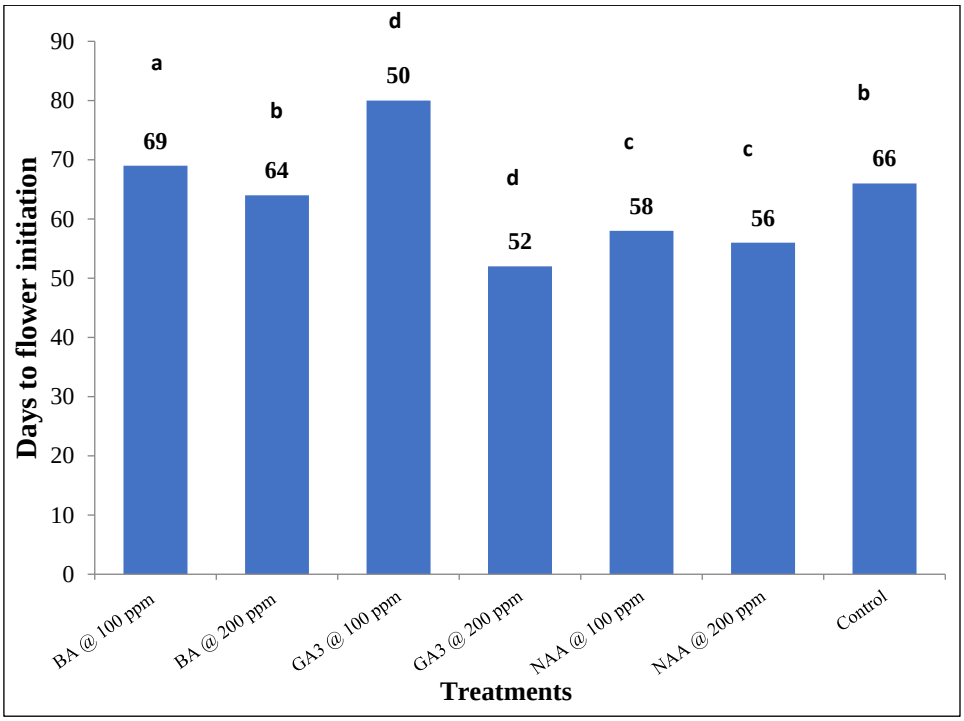

Fig. 1. Effect of BA, GA_3 and NAA on flower initiation in chrysanthemum. Mean values on top of the bars with uncommon letter(s) are significantly different at 1% probability by DMRT.

Stalk length and rachis length

From marketing point of view, length of flower stalk is an important parameter of flower growth. Using GA_3 at 100 ppm concentration gave the maximum stalk length (37.5 cm) and rachis length (29.0 cm), compared with other PGR (BA and NAA) concentrations and control, which were statistically similar to those of GA_3 @ 200 ppm (34.6 cm and 25.0 cm). Minimum stalk length (26.5 cm) and rachis length (18.0 cm) were observed in BA @ 100 ppm closely followed by BA @ 200 ppm and NAA @ 100 ppm and control. This is in close conformity with the result of Singh *et al.* (201) who obtained maximum stalk length using GA_3 @ 150 ppm being identical with GA_3 @ 100 ppm in chrysanthemum. The increased stalk length with GA_3 @ 100 ppm treatment might be due to rapid internodal elongation, rapid cell division and cell elongation in the intercalary meristem. Singh *et al.* (2018) opined the reason of increased stalk might be that the flowers stalk length due to redirecting the movement of organic metabolism and in establishing sink. The increase in rachis length with GA_3 @ 100 ppm might be due to increased activity of growth promoting enzymes by synthesizing more nucleic acid and other

compounds. Whereas, the minimum rachis length with BA @ 100 ppm might be due to BA showed reduced plant height and stalk length, which directly influenced the rachis length.

Table 2. Effect of plant growth regulators on flowering parameters of chrysanthemum

Treatments	Stalk length (cm)	Rachis length (cm)	Flower number/plant	Flower size (cm)	Av.weight of stalk (g)
BA @ 100 ppm	26.5 c	18.0c	15.0 c	6.7 ab	25.5 c
BA @200 ppm	30.0 bc	20.8 bc	19.0 bc	6.8 ab	26.8 bc
GA_3 @100 ppm	37.5 a	29.0 a	26.0 a	7.8 a	37.0 a
GA_3 @200 ppm	34.6 ab	25.0 ab	23.5 ab	7.2 ab	36.0 ab
NAA @100 ppm	31.8 bc	21.5 bc	18.5 ab	7.0 ab	29.0 ab
NAA @200 ppm	32.5 b	22.0 bc	20.0 b	7.1 ab	31.0 b
Control	30.0 bc	22.7 b	17.0 bc	6.0 b	26.5 bc
CV (%)	7.5	7.2	8.6	6.9	8.7

In a column mean values with common letters do not differ significantly at 1% level of probability by DMRT

Number of flowers per plant

Plants treated with GA_3 @ 100 ppm concentration produced maximum number of flowers per plant (26.0) which was identical with GA_3 @ 200 ppm (23.5/plant) and NAA @ 100 ppm (18.5/plant), but BA @ 100 ppm treatment produced the lowest number of flowers per plant (15.0) being identical with BA @ 200 ppm (19.0/plant) and control treatment (17.0/plant) (Table 2). The increase in flower numbers by GA_3 with a specific concentration 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 flower production.

Alhajhoj (2017) also reported that application GA_3 @ 300 ppm gave maximum number of flowers per plant which was identical with that of GA_3 @ 200 ppm. Patel *et al*. (2018) obtained the highest number of flowers per plant from GA_3 @ 150 ppm being identical with GA_3 @ 100 ppm. Sharifuzzaman *et al*. (2011) and Singh *et al*. (2018) obtained maximum number of flowers per plant from the spraying of GA_3 @ 150 ppm which was significantly higher than GA_3 @ 150 ppm. Sahu *et al.* (2021) and Sajid *et al*. (2016) reported maximum number of flowers per plant was from GA_3 @ 200 ppm and GA_3 @ 250 ppm, respectively.

Flower size

Maximum size of flower (7.8 cm) was observed with GA_3 @ 100 ppm concentration which was statistically similar to GA_3 @ 200 ppm (7.2 cm), NAA (100 and 200 ppm) and BA (100 and 200 ppm) and the lowest flower size was observed in control (Table 2). Singh *et al.* (2018) and Sharifuzzaman *et al.* (2011) obtained maximum flower size from GA_3 @ 150 ppm. Frag *et al*. (2018) and Sajid *et al.* (2016) reported that using GA_3 @ 200 ppm gave the maximum flower size, whereas Alhajhoj (2017) was found flower size maximum from GA_3 @ 300 ppm treated plant. The result of increased flower size with GA_3 was probably due to that using gibberellic acid at a proper concentration led to extend the length of ray florets, or promote more initiated florets per capitulum or both of them, accordingly the flower size of chrysanthemum plant would be increased (Frag *et al*.,2018). Singh *et al*. (2018) opined regarding the cause of increased flower size with GA_3 at a specific concentration that it may have been due to a close parallelism between vegetative growth and flowering and it is possible that stimulatory effect of GA_3 on vegetative growth associated with efficient mobilization capacity.

Weight of stalk (Average)

The average fresh weight of stalk (37.0 g) was recorded to be the maximum with treatment involving GA_3 @ 100 ppm closely followed by 36.0 g weight with GA_3 @ 200 ppm and NAA @ 100 ppm (29.0 g). The minimum weight (25.5 g) in stalk harvested from the pot where plants were sprayed with BA @ 100 ppm which was identical with normal water (control) (26.5 g). Singh and Bala (2018) obtained increased stalk weight compared to control when GA_3 was applied at the rate of 50, 100 and 150 ppm. However, they obtained maximum stalk weight from GA_3 @ 150 ppm being identical with GA_3 @100 ppm. Increase in weight of stalk might be due to increased activity of enzymes which are involved in cell division and elongation process.

Vase life

Treatment consisting of GA_3 @ 100 ppm significantly produced maximum vase life (flower life) (15 days) which was closely followed by that of GA_3 @ 200 ppm (14 days) and minimum vase life in control treatment (10 days) (Fig. 2). It is observed that flower life was increased by 5 days when the solution of GA_3 @ 100 ppm was used. This is in agreement with the results of Sajid *et al.* (2018) and Sharifuzzaman *et al.* (2011) who obtained maximum vase life from the chrysanthemum plants treated with 100 ppm GA_3 closely followed by 150 ppm GA_3. Talukder and Paswan (1998) also reported that application of GA_3 at 40 ppm concentration increased vase life by 9 days in chrysanthemum.

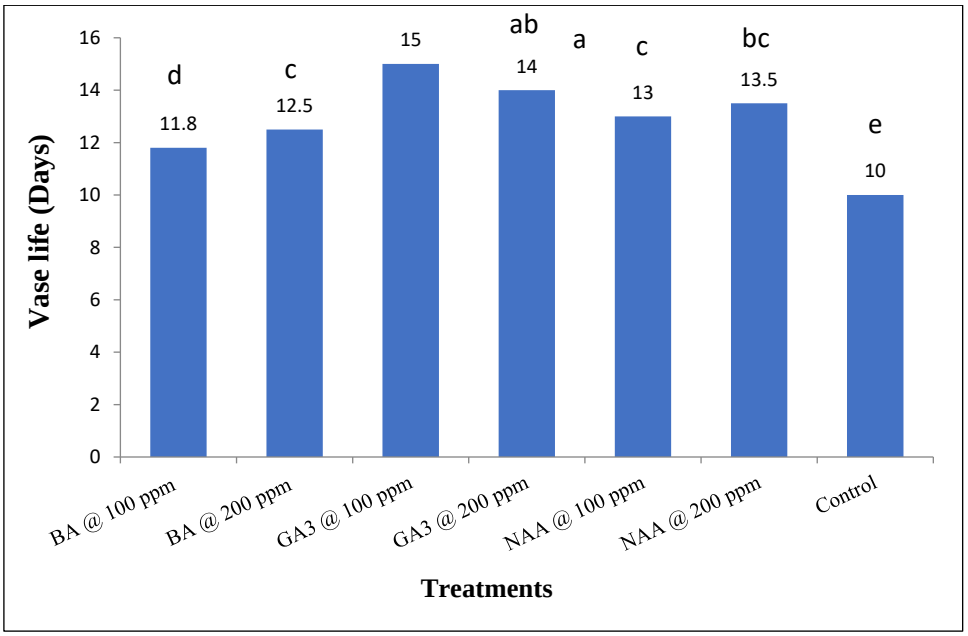

Fig. 2. Effect of BA, GA_3 and NAA on vase life in chrysanthemum. Mean values on top of the bar with uncommon letter(s) are significantly different at 1% probability by DMRT.

Sajid *et al.* (2018) explained that the vase life could be correlated with ethylene production which is inhibited by the foliar application of GA_3, because it may had retarded the onset of senescence in whole cut inflorescence stalk by containing higher amount of RNA content. Farag *et al.* (2018) gave the same opinion that the increased vase life was probably due to that using GA_3 at a suitable concentration led to delay the flower's senescence and reduce ethylene production in the cut flowers, consequently the flower duration in the vase could be increased.

Conclusion

Vegetative growth and flowering parameters of chrysanthemum as well as vase life of flowers were influenced by the application of plant growth regulators, namely GA_3, BA and NAA in chrysanthemum. GA_3 @ 100 ppm was superior regarding plant height and plant spread and all flowering traits and reduced time to flower initiation by 16 days for early bloom. The same treatment also increased vase life of flowers by 5 days. From the present study, it is concluded that foliar application of GA_3 @ 100 ppm was superior for obtaining better vegetative growth of plants, maximum number of flowers with longer stalk as well as bigger flower size with prolonged vase life in chrysanthemum

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