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Research Article

EFFECT OF GIBBERELLIC ACID ON PLANT GROWTH AND FLOWERING OF *CHRYSANTHEMUM CV*. THAI CHEN QUEEN UNDER SHORT DAY PLANTING CONDITIONS

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Abstract: An experiment was conducted to study the effect of GA_3 on plant growth, flowering and its role in substituting the artificial light conditions in chrysanthemum cv. Thai Chen Queen. Three different concentrations (200 mg/L, 300 mg/L and 400 mg/L) of GA_3 were sprayed at two different intervals (7th day and 14th day after transplanting) on plants grown in protected conditions during short days. Observations on vegetative and reproductive parameters were recorded during 30, 45 and 60 days after planting. Vegetative growth characteristics like plant height (45.1 cm), inter-nodal length (2.28 cm), and leaf number (28) were more superior in GA_3 treated plants compared with control. Plant fresh and dry weights, leaf area index (LAI), net assimilation rate (NAR) and photosynthetic pigments; chlorophyll and carotenoid contents were increased with GA_3 application. GA_3 application also causes early bud induction in *Chrysanthemum cv.* Thai Chen Queen. Floral parameters like bud diameter, flower diameter, fresh weight and dry weight as well as increased vase-life of the flowers were observed in GA_3 treated plants. GA_3 application helps to substitute artificial light conditions which are required for the vegetative growth of the chrysanthemums and also helps to improve the flower quality under short day conditions.

Keywords: *Chrysanthemum*, flowering, GA_3, short day planting conditions

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Introduction

Chrysanthemum (*Chrysanthemum morifolium*) is a popular cut flower crop, probably ranks next to rose in the international cut flower market. *Chrysanthemum* is a typical short day plant which requires long day conditions for proper vegetative growth of the plant and short day conditions for flower bud induction as well as development. Minimum length of continuous dark or light period which is required for flower bud initiation is found to be 9-9.5h of night (or) 14-14.5h of day [1]. *Chrysanthemum* is having an inherent sensitivity to naturally available photoperiod and temperature limits. Delayed planting of *Chrysanthemum* leads to poor flower quality with short stem length and vase life. Under north Indian conditions, *Chrysanthemum* planting is done during July and August months; so that initial long day and subsequent short day conditions facilitate proper vegetative and reproductive growth of the plants. For off-season cultivation of the *Chrysanthemums* (if planting is done under short day conditions) there is a need to provide artificial light and dark conditions subsequently in order to get quality cut flowers. Gibberellic acid (GA_3) is a plant growth hormone which influences plant growth in many ways; promotes stem elongation and consequently enhances growth, modifies the light requirement and influences the flower bud initiation. Previous reports indicated that GA_3 had remarkable effect on *Chrysanthemum* plant growth and flowering [2-18]. Increased plant height, stem diameter and number as well as length of shoots per plant were observed in *Chrysanthemum* with the application of GA_3 [19]. GA_3 at 150 ppm was most effective for the growth and flowering response of *Chrysanthemum* compared to other growth regulators *viz*., NAA, maleic hydrazide and CCC [20].

Studies were also done to access the influence of GA_3 at 50,100 and 200 ppm on growth, flowering and cut flower yield in *Chrysanthemum cv*. Jayanti and reported its positive effect at all concentrations, optimum was at 100 ppm GA_3 [21]. GA_3 at 200 ppm resulted in maximum plant height (95.96 cm), number of branches per plant (27.13) and maximum number of flowers per plant (148.73) while 50 ppm gives early flower formation [22]. Improvement in the photosynthetic plant pigments like chlorophyll and carotenoids were also observed with GA_3 application [19]. The effect of GA_3 after flower budding on the flowering and cut flower quality of summer-to-autumn flowering small-flowered spray type *Chrysanthemums* harvested in August was studied and reported that GA_3 application (100-200 ppm, twice) after the bud break stage accelerates flowering without reduction in quality of cut flower [23]. In present study, *Chrysanthemum* planting was undertaken during short day conditions. Instead of providing artificial light and dark conditions for off-season flowering, we have treated the plants with three different concentrations of GA_3. Effect of GA_3 on plant growth and flowering and its role in substituting the artificial light conditions were studied.

Materials and Methods

One month old self rooted cuttings of *Chrysanthemum cv*. Thai Chen Queen were planted at 5-7 leaf stage on well prepared beds in naturally ventilated polyhouse during winter season. The experiment was laid out in randomized block design (RBD) with four replicates, each containing 40 plants with a spacing of 20×20 cm between rows and plants on 2 sqm (1 m width × 2 m length) beds. In early stages of vegetative growth, a continuous application of N:P:K at the rate of 20:20:20 was

given as fertigation and later fertilizer ratio was changed to 100:50:150 after well establishment of the transplants. Fertigation was restricted only with KNO_3 at a stage when marble size bud was achieved. However, fertilizer application was stopped completely at the stage of flower colour appearance. De-shooting was carried out by leaving one terminal bud when the auxiliary buds were large enough to handle. A frequent disbudding operation was also carried out after terminal bud initiation. Three concentrations of GA_3 (200, 300 and 400 mg/L) were applied as foliar spray on plants at 7 and 14 days of planting and observations were recorded at three different intervals *i.e.* 30, 45 and 60 days after transplanting of *Chrysanthemum*. Morphological observations on plant height, stem diameter, leaf number, inter-nodal length, fresh and dry weights of stem, foliage and root were measured and recorded. Leaf area was measured by leaf area meter, Li-Cor (Model 3100). NAR [24], RGR [25], LAI [24] were measured on the basis of dry weight, leaf and ground area at 15 days interval after 30 days of transplanting. Observations on floral parameters *viz*. number of days for flower bud initiation, flower bud diameter (cm), days taken for full opening of the flower, flower diameter (cm) and fresh and dry weights (g) of the flowers were also recorded. Total chlorophyll and carotenoid contents from the leaf samples were measured using DMSO method [26]. For observing post-harvest life of the cut flowers, GA_3 treated and untreated cut stems were collected from poly house in the morning to avoid excessive heat and brought to the laboratory in a bucket containing 3-4 litres 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. For measuring different physiological parameters like cut flower vase life (days), flower opening (cm), total vase solution uptake (ml), changes in the mean fresh weight of the flowers (g) (on 1st, 7th, 14th and 20th day), membrane stability index values of the petals (µs) (on 1st and 14th day) were recorded. For determining the vase life of the *Chrysanthemum* cut flowers (days), wilting of both leaves and flowers were used as the criterion. Visual rating of leaves and flowers senescence were evaluated periodically during the vase life of flowers. Evaluation was done based on a scale ranging from 1 to 4 where: 1= entirely green leaves and good flowers, 2= initiation of wilting in 25%, 3= wilting in 25-50% and 4= wilting in 50-100% of leaves as well as flowers. The longevity of *Chrysanthemum* cut flowers was defined as the number of days in vase life required for 50% of the flowers to reach stage 2 or advanced stages.

Statistical analysis

The experimental data on vegetative and flowering parameters were subjected to ANOVA and the differences among treatments were analyzed by Duncan's Multiple Range Test (DMRT) with statistical package SAS 9.2 version. The test was done to separate means showing significant differences in all treatments and their combinations. To examine the effect of GA_3 on post- harvest life of the flowers experiment was arranged in CRD with three replications and the analysis was done using OPSTAT.

Results and Discussion

Vegetative growth parameters: Plant height and Inter-nodal length

A significant increase in plant height was observed with the application of GA_3 in *Chrysanthemum cv*. Thai Chen Queen compared to untreated plants [Table-1]. Rate of increase in plant height was more during initial 45 days after planting. Maximum length (45.09 cm) of the cut stems were observed in plants treated with 400 mg/L GA_3 and the variation between the maximum value and control is 16.42 cm. Variation could be due to more number of nodes as well as internodal length in treated plants. A significant difference for number of nodes and internodal length was also observed among different concentrations of GA_3. But the variation between the different concentrations of GA_3 for plant height was not constant in later stages of plant growth. The positive response for increase in the number of nodes, internodal length and plant height was due to the effect of GA_3 on stimulation of cell division as well as elongation of new cells formed in the plants [27]. Similar results were also reported in many studies in *Chrysanthemum* [7, 10, 11, 13, 15, 28]. Slower growth rate of the plant after 45 days of planting may be due to the initiation of short day conditions which stops further vegetative growth of the *Chrysanthemum*, in order to stimulate flower bud initiation.

Stem diameter (cm)

No significant difference for stem diameter was observed with application of GA_3 [Table-1]. On the contrary to the present results, certain reports observed increased stem diameter in *Chrysanthemum* with the application of 100 mg/L GA_3 [29]. In the present experiment minor variations in the stem diameter for different GA_3 concentrations may be due to increased cell elongation and internodal lengths in treated plants. Since *Chrysanthemum* is obligate short day plant, internal genetic behaviour of the plant hastens flowering without sufficient vegetative growth due to the absence of required light conditions.

Leaf number per plant

Number of leaves also increased with increase in the concentration of GA_3 in *Chrysanthemum cv*. Thai Chen Queen and significant differences observed between the treatments during three intervals (30, 45 and 60 days of planting) [Table-1]. Similar results obtained with 10, 20, 40 mg/L of GA_3 application in Snowball, Kiku Biori and Lilac cultivars of standard *Chrysanthemum* [7]. Application of GA_3 at 150 ppm as foliar spray in *Chrysanthemum* resulted in highest number of leaves [17]. These results might be due to GA_3 enhanced biosynthesis of proteins and carbohydrates leading to enhancement of initiation of leaf primordial growth and consequently production of more leaves [30]. In this experiment we observed an increase in the levels of photosynthetic pigment values in GA_3 treated plants compared to control. Application of GA_3 helps in increased photosynthesis and accumulation of more storage compounds accounting for rapid growth of leaf primordia.

Fresh and dry weights of the stem (g)

Fresh and dry weights of the stems were increased with increased duration of plantation. Significant differences between the treatments and control values were observed during three intervals *i.e*. 30, 45 and 60 days after planting [Table-1]. When these treatments were compared with the control, an increase of 44%, 54% and 58% stem dry weights were observed with 200 mg/L, 300 mg/L, 400 mg/L GA_3 application respectively after 30 days of planting. During later stages of plant growth (60 days after planting) *cv*. Thai Chen Queen recorded maximum value (0.94 g) with 400 mg/L GA_3 concentration, which was 51% more than control (0.43 g) value. The increase in fresh and dry weights of the stem with GA_3 application may be due to the increase in the photosynthetic assimilation. Accumulation of photosynthates might be enhanced in the treated plants, with an increase in photosynthetic pigments (chlorophyll and carotenoids) as well as root function. In the present study cultivation of the *Chrysanthemum* were undertaken during short day conditions, this kind of photoperiodic condition was not suitable for synthesis of GA_3, which is required for vegetative growth of the plant. External substitution of this hormone might be helpful in increased vegetative growth as well as dry matter accumulation in the plant stems. Similar results were reported with GA_3 application in plant Thalspi arvense [31].

Fresh and dry weight of the leaves (g)

Fresh and dry weights of the leaves were increased with increased concentrations of GA_3 in *Chrysanthemum cv*. Thai Chen Queen and maximum value obtained after 60 days after planting and with 400 mg/L GA_3, a 41.4 % and 41.9 % increase over control values [Table-1]. The increase in leaf weight of the plants treated with GA_3 was due to increase in leaf number as well as leaf size whereby dry matter accumulated from the increased levels of photosynthetic pigments like chlorophylls and carotenoids. A similar result with GA_3 was also observed in *Chrysanthemum frutescence* [17].

Fresh and Dry weights of the Root (g)

Fresh and dry weights of the roots were increased over the time with the application of GA_3.

Maximum values were recorded after 60 days of planting with 400 mg/L GA_3 which were 23.5% and 29.7% more than the control values [Table-1]. Increase in fresh and dry weight of the roots and root area reveals maximum absorption of minerals by roots which were further used by plant for different metabolic actions within the plant system. The absorption and utilization of mineral nutrients has a significant role in the membrane permeability and transport of assimilates [32-35]. Similar results with increased dry matter production of roots were observed in *Bougainvillea glabra, Rosa chinensis* and *Ixora coccinea* plants with 200 mg/L GA_3 application [36].

Leaf area index (LAI)

An incremental change in LAI was observed after 30, 45 and 60 days after planting [Table-1]. In later stages of plant growth variations were significantly different than the control. In the present study, we observed an increase in the leaf number as well as leaf area with the application of GA_3. This increase in leaf area is because of GA_3 induced cell division as well as expansion in the plants [37]. Previous studies reported an increase in plant spread, leaf number as well as leaf length in GA_3 treated plants of *Chrysanthemum* [17].

Total chlorophyll and carotenoids (mg g-1 FW)

The results presented in the [Table-2] indicated significant increase in chlorophyll content in GA_3 treated plants over control. After 60 days of planting, chlorophyll values were reduced little over first interval and values were found to be significant between the treatments and showing the same trend like first interval reading. Carotenoid values were more or less similar in both the intervals and a significant difference in carotenoid values was also observed between the treatments with different concentrations of GA_3. Maximum carotenoid value (1.66 mg g-1 FW) was reported with 400 mg/L which is 17% more than the control value. Synthesis of photosynthetic pigments in the plant system helps in assimilation of more photosynthates and accumulation of more dry matter in the plants. During rapid vegetative growth of the plants (initial 30 days after planting) more chlorophyll concentration was observed and in later stages of its growth slight reduction was noticed due to cessation of vegetative growth and initiation of reproductive growth. An increase in root membrane permeability would facilitate absorption and utilization of mineral nutrients and transport of assimilates [32-35]. These cellular changes towards increase in protein metabolism might be the reason for increase in chlorophyll and carotenoids. Similar findings were observed in *Chrysanthemum frutescence* with application of GA_3 100-1000 mg/L [19].

Relative growth rate (RGR) (g g-1 day-1)

Relative growth rate is a plant growth measure, used to quantify the speed of plant growth. It is calculated after 30 and 60 days after planting. Minor differences were found between treated as well as control plants for RGR values [Table-2]. But significant differences were not found between the treatments values during both the intervals. After 30 days of planting minor increase was observed with the increased concentration of GA_3. RGR was calculated based on differences of dry weight of the plants under specific time duration. Because of the minimal differences in the dry weight gain of the different treatments during first 30 days of planting duration, differences in the RGR values was also found to be minimal. In the later stages of the plant growth RGR values were increased than first interval values. Dry weight gain in the second interval is mainly because of standard flower weight, the flower weight observed was more or less similar in different treatments and further vegetative growth was also ceased because of cut flower initiation in the *Chrysanthemum*s. Second interval RGR values between the treatments, found to be non-significant in *cv*. Thai Chen Queen, maximum value (0.064 g g-1/day) was observed with 200 mg/L GA_3 treatment, which was followed by 300 and 400 mg/L GA_3 treatments respectively. However, in both the intervals treatment RGR values were found to be more over control values. Likewise increased RGR values with increased concentration of GA_3 were observed in Pelargonium [38].

Net assimilation rate (NAR) (mg cm-2 day-1)

Net Assimilation Rate is a useful measure to check the photosynthetic efficiency of the plants. NAR values were recorded after 30 and 60 days of planting. During initial interval of planting (*i.e*. first 30 days after planting), NAR values were found to increase with application of GA_3. But significant differences were not found between different treatment values. During second interval NAR values were increased over first interval but values were also not significant like first interval. However treated plant was showing maximum values compared to control during both the intervals [Table-2]. The above finding clearly indicates that GA_3 (probably as a consequence of its marked influence on stem elongation) accelerated mobilization of photosynthates from the leaves to the stem. Higher NAR in plants treated with GA_3 was probably as a result of rapid removal of photosynthates from the leaves.

Flower related parameters

Days to buttoning and flower opening

Flower bud initiation in the *Chrysanthemum cv*. Thai Chen Queen was occurred after 35 days of planting. Here significant differences between the treatment and control values were not observed and this measure was more or less similar trend in all the plants [Table-3]. Flower development and opening also hastened in GA_3 treated plants compared to control. Significant differences were not found in treated as well as control plants. Since *Chrysanthemum* is a short day plant, pre availed short day conditions might be responsible for early flower bud initiation as well as flower opening. The minor differences in buttoning and flower opening might be due to strong influence of pre availed short day conditions. In addition to this, GA_3 also responsible for hastened flower bud initiation in most of the plants. Earlier reports observed an advanced flower bud induction in *Chrysanthemum* frutescens [19]. A similar kind of reports with early flower bud induction was also reported in gladiolus, carnation and tube rose [39-41].

Bud and flower diameter

Bud diameter values varied significantly among the GA_3 treated plants and recorded a maximum bud diameter of 1.71 cm with 300 mg/L as compared to control [Table-3]. It was evident from the data that with an increase in the concentration of GA_3 (*i.e*. 200, 300 and 400 mg/L), there was only 3%, 7.6% and 6.5% increase in the bud diameter over control. The flower diameter also increased with the increasing dose of GA_3 treatment. Maximum flower diameter recorded was 11.9 cm with 400 mg/L GA_3. Increased biomass production due to the application of GA_3 might be responsible for enhanced flower quality parameters like flower and flower bud diameter values. Similarly, in the case of carnation increased flower quality parameters with the application of GA_3 was observed [41].

Fresh and dry weight of the flower

The increase in fresh and dry weight values of the flower were maximum 30.4% and 48.18% more in GA_3 treated plants compared to control. The fresh and dry weight values of the treated plants were more or less similar at all the three concentrations and maximum values GA_3 application might have resulted in quality reproductive growth of the treated plants further. This could be a reason for increased fresh weight and dry weight of the flowers. This results obtained from this study were also in close agreement with those obtained in carnation [41, 42].

Effect of GA_3 on Vase life of the flowers

Data presented in the [Table-4] revealed that the flower vase life in GA_3 treated plants increased up to 19.9 days as compared with flowers harvested from untreated plants (17.37 days). The vase life obtained with the treated plants was almost 2.5 days higher than the control cut flowers. Increased vase water uptake, flower bud opening in the vase solution, membrane stability index and mean fresh weight values of the cut stems were found to be more in treated plants values compared to the control. This prolonged vase life of GA_3 treated cut flowers might be due to strong flowering stems with more flower bud size. Because of the higher vigour in treated plants, cut stems may also contain more food reserves. In addition to this, increased water uptake and water holding capacity in treated cut stems might be a reason for increased vase life in GA_3 treated cut stems over untreated ones. Few other studies also report increase in flower vase life with the application of GA_3 in *Chrysanthemum* flowers [29, 43].

Table-1 Effect of gibberellic acid on plant vegetative growth in *Chrysanthemum morifolium cv*. Thai Chen Queen

Treatment	Plant height (cm)	Internodal length(cm)	Stem diameter(cm)	Number of leaves	Stem FW	Stem DW	Leaf FW	Leaf DW	Root FW	Root DW	LAI
30 DAP											
T0	19.44^{f}	0.75^{c}	0.34^{a}	18.79^{c}	1.81^{d}	0.15^{d}	5.03^{e}	0.52^{c}	1.01^{b}	0.10^{b}	0.24^{c}
T1	25.95^{bcd}	1.03^{bc}	0.34^{a}	23.66^{b}	2.47^{cd}	0.27^{cd}	5.63^{de}	0.51^{c}	1.1^{ab}	0.11^{b}	0.32^{b}
T2	28.37^{ab}	1.13^{abc}	0.39^{a}	24.69^{ab}	2.55^{cd}	0.33^{bc}	5.97^{de}	0.61^{bc}	1.28^{a}	0.13^{ab}	0.40^{a}
T3	29.07^{a}	1.13^{abc}	0.39^{a}	26.75^{a}	3.77^{b}	0.36^{bc}	6.67^{d}	0.70^{b}	1.39^{a}	0.14^{a}	0.43^{a}
SEm±	0.76	0.13	0.02	0.64	0.19	0.04	0.17	0.04	0.07	0.01	0.01
CD at 5%	2.48	NS	NS	2.074	0.62	0.14	0.55	0.12	0.23	0.03	0.04
45DAP											
T0	27.59^{f}	1.26^{d}	0.52^{d}	21.96^{f}	3.63^{f}	0.15^{d}	5.50^{f}	0.57^{f}	1.70^{f}	0.16^{d}	0.44^{f}
T1	38.21^{d}	1.75^{c}	0.53^{cd}	25.46^{de}	5.80^{e}	0.27^{cd}	6.69^{ef}	0.65^{f}	2.07^{ef}	0.20^{cd}	0.59^{ef}
T2	40.85^{cd}	2.04^{bc}	0.54^{bcd}	26.39^{de}	6.55^{de}	0.33^{bc}	7.93^{ef}	0.80^{ef}	2.31^{de}	0.22^{c}	0.69^{de}
T3	43.43^{bc}	2.15^{bc}	0.54^{bcd}	27.53^{cd}	7.98^{cd}	0.36^{bc}	9.05^{e}	0.90^{e}	2.53^{d}	0.25^{c}	0.82^{cd}
SEm±	1.6	0.1	0.02	0.74	0.2	0.04	0.23	0.02	0.098	0.01	0.02
CD at 5%	5.18	0.31	NS	2.41	0.66	0.14	0.74	0.07	0.319	0.04	0.06
60DAP											
T0	28.67^{f}	1.45^{d}	0.59^{b}	22.89^{d}	4.75^{d}	0.15^{d}	10.30^{g}	1.01^{e}	2.83^{e}	0.26^{e}	0.50^{f}
T1	39.98^{e}	1.89^{c}	0.58^{b}	26.36^{c}	6.88^{c}	0.27^{cd}	14.48^{f}	1.38^{de}	3.19^{de}	0.31^{d}	0.73^{ef}
T2	41.64^{de}	2.09^{bc}	0.57^{b}	26.45^{c}	7.61^{c}	0.33^{bc}	17.10^{e}	1.59^{d}	3.38^{cd}	0.34^{cd}	0.85^{de}
T3	45.09^{cd}	2.28^{ab}	0.57^{b}	28.12^{c}	8.34^{c}	0.36^{bc}	17.58^{de}	1.74^{d}	3.70^{c}	0.37^{c}	0.99^{cd}
SEm±	1.53	0.11	0.01	0.5	0.23	0.04	0.44	0.06	0.1	0.01	0.02
CD at 5%	4.97	0.37	NS	1.65	0.74	0.14	1.43	0.19	0.325	0.03	0.08

DAP- Days after planting; FW- Fresh weight, DW- Dry weight; LAI- Leaf area index

Table-2 Effect of GA_3 on plant growth parameters in *Chrysanthemum morifolium cv*. Thai Chen Queen

Treatment	Days to buttoning	Bud diameter (cm)	Day to flower opening	Flower diameter (cm)	FW of the flower (g)	DW of the flower (g)
T_1	38.19^{a}	1.58^{c}	83.54^{a}	10.083^{b}	16.28^{b}	1.10^{b}
T_2	36.95^{a}	1.63^{bc}	80.12^{ab}	11.508^{a}	19.18^{ab}	1.39^{a}
T_3	35.56^{a}	1.71^{a}	78.15^{b}	11.533^{a}	20.49^{a}	1.57^{a}
T_4	35.97^{a}	1.69^{ab}	78.31^{b}	11.998^{a}	21.23^{a}	1.63^{a}
SEm±	0.79	0.02	1.25	0.25	1	0.08
CD at 5%	NS	0.08	4.05	0.8	3.25	0.24

Table-3 Influence of GA_3 on flower quality parameters in *Chrysanthemum cv.*Thai Chen Queen

Treatment	Total chlorophyll	Carotenoids	Crop growth rate	Net assimilation rate	Relative growth rate
30 DAP					
T0	1.34^{e}	1.36^{bc}	0.022^{e}	0.129^{b}	0.026^{b}
T1	1.58^{bcd}	1.40^{bc}	0.039^{cde}	0.177^{b}	0.033^{ab}
T2	1.76^{b}	1.46^{ab}	0.046^{bcd}	0.174^{b}	0.034^{ab}
T3	2.02^{a}	1.66^{a}	0.055^{de}	0.183^{b}	0.035^{ab}
SEm±	0.07	0.05	0.005	0.02	0.005
CD at 5%	0.22	0.16	0.02	NS	NS
60 DAP					
T0	1.28^{c}	1.36^{c}	0.06^{c}	0.264^{c}	0.041^{b}
T1	1.55^{abc}	1.46^{bc}	0.15^{b}	0.472^{a}	0.064^{a}
T2	1.73^{ab}	1.46^{bc}	0.17^{ab}	0.439^{ab}	0.059^{a}
T3	1.75^{ab}	1.65^{ab}	0.18^{a}	0.394^{b}	0.056^{a}
SEm±	0.07	0.04	0.007	0.02	0.002
CD at 5%	0.22	0.13	0.02	0.07	NS

Table-4 Effect of pre-treated GA_3 application on vase life of the cut flowers in *Chrysanthemum cv.* Thai Chen Queen

Treatment	Flower diameter (cm)	Water uptake (ml)	Vase life (days)	Membrane stability index(MSI) (µs)		Mean fresh weight Changes (g)			
				Day-1	Day-14	Day-1	Day-7	Day14	Day-20
T_1	8.73	39.01	17.37	50.7	48.42	15.42	17.62	15.09	13.05
T_2	9.27	43.71	18.62	61.31	60.65	17.85	20.47	18.17	16.65
T_3	9.93	43.09	19.45	61.44	61.29	18.90	21.72	19.82	18.05
T_4	9.34	42.82	19.90	62.82	61.7	18.71	22.41	20.91	19.64
SEm±	0.16	1.39	0.39	2.39	1.61	0.75	0.67	0.59	0.48
CD at 5%	0.54	NS	1.29	7.91	5.34	2.47	2.21	1.94	1.60

Conclusion

Vegetative and reproductive growths of plants as well as post-harvest life of the flowers were influenced by GA_3 application in *Chrysanthemum morifolium cv*. Thai Chen Queen under short day conditions. With the increasing concentration of GA_3 enhancement in the vegetative growth measures like plant height, fresh and dry weight of the plants, leaf number, LAI, NAR, and RGR values were also observed. In addition to this, acceleration of bud induction, increased flower diameter, fresh and dry weight of the flowers as well as vase-life also influenced by GA_3 application. From the present study we can conclude that plant hormone GA_3 helps in maintaining the plant vigour as well as flower quality even under short day planted conditions. Here we used single variety of the *Chrysanthemum* with only three concentrations of GA_3 (200 mg/L, 300 mg/L and 400 mg/L). Increase in vegetative and reproductive growth of the plants was observed with increasing concentration of GA_3. In depth study with use of more number of varieties, higher concentration of GA_3 might give better results.

Application of research: As minimal amount of GA_3 *i.e*. 200-400 mg/L suffices the need for artificial light, it is economical and can be leveraged by farmers for the growth of off-season cultivation of *Chrysanthemum*s under protected conditions. It also eliminates the need of manpower to provide controlled artificial light.

Abbreviations: GA_3- Gibberellic acid, LAI- Leaf area index, NAR- Net assimilation rate, RGR- Relative growth rate, DMSO- Dimethyl sulfoxide

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