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EFFECT OF HUMIC ACID CONCENTRATIONS ON VEGETATIVE, FLORAL ATTRIBUTES AND ECONOMICS OF CHRYSANTHEMUM (*DENDRANTHEMA GRANDIFLORA* TZVELEV) VAR. GARDEN BEAUTY UNDER HILLY CONDITION OF UTTARAKHAND INDIA

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ABSTRACT

In a naturally ventilated polyhouse, a study was performed to analyze the effect of foliar humic acid application on growth, flowering attributes and economics of the chrysanthemum (*Dendranthema grandiflora* Tzvelev) var. Garden Beauty in the temperate region of Uttarakhand. The experiment was laid out from June 2022 – February 2023 in a randomized complete block design (RCBD) with four replications, incorporating six treatments of humic acid concentrations, *viz*: T_1: Control, T_2: 0.2%, T_3: 0.4%, T_4: 0.6%, T_5: 0.8% and T_6: 1.0%. Rooted cuttings were transplanted in raised beds at a spacing of 30 cm × 30 cm. According to the results, significant effects were shown in all the parameters during the experiment. Plants sprayed with 0.6% humic acid resulted in tallest plants (102.75 cm), maximum number of primary branches per plants (8.10), number of leaves per plant (180.32), plant spread (44.30 cm) and leaf area (22.67 cm^2). Similarly in case of floral attributes the same treatment *i.e.* 0.6% humic acid showed earliness in 1st bud appearance (64.85 days), first flower opening (94.50 days), days taken for 50% flowering (104.50 days), maximum flowers per plant (89.00), number of flowers per plot (988.42), maximum cut sprays per plant (21.25), maximum flower diameter (11.95 cm), spray length (59.29 cm), vase life (14.50 days), maximum gross return (53,111.00 ₹/100m^2), Net return (27,643.46 ₹/ 100m^2) and cost benefit ratio (1:1.09). However, plants treated with 0.4% humic acid showed a prolonged duration of flowering (24.75 days). The experiment concludes that foliar application of humic acid at 0.6% was found most effective and economical viable for enhancing flower production of chrysanthemum in temperate region of Uttarakhand.

Key words: Humic acid, Chrysanthemum, naturally ventilated polyhouse, Bharsar, Vegetative, Floral attributes and Economic.

Introduction

Chrysanthemum (*Dendranthema grandiflora* Tzvelev) belongs to family Asteraceae (Anderson, 1987) is one of the most significant traditional flowers, widely recognized and commercially cultivated as an ornamental crop due to its ornamental and economic value (Li *et al*., 2013 and Ren *et al*., 2013). It is native to Northern hemisphere chiefly Europe and Asia having chromosome number n=9. It holds a prominent position in floriculture and rank fifth as a pot plant globally, while being the second- most important cut flower crop worldwide (Singh and Godara, 2021). The word 'Chrysanthemum' is derived from two Greek words *chrysos* meaning golden and *anthos* meaning flower, reflecting its historic association with golden-hued flowers and popularly known as Queen of East, Glory of East, Autumn Queen and Mums (Arora,

1999). Chrysanthemum is grown as for cut flower, loose flower, potted plant and as border plant or garden display and gaining popularity due to its availability of wide range of flower colours, sizes, shapes, forms and textures (Randhawa and Mukhopadhyay, 2001). In India, it is commercially cultivated in open fields and protected polyhouses on an area of 23.93 Th ha with a total production of 470.16 Th Tonnes out of which loose flower production is 454.20 Th Tonnes and cut flower production is 15.96 Th Tonnes during 2021-2022 (NHB, 2022). The maximum area under chrysanthemum cultivation is in Karnataka (10.35 Th ha) followed by Tamil Nadu (6.91 Th ha), Andhra Pradesh (3.00 Th ha), Madhya Pradesh (1.32 Th ha) and Telangana (0.85 Th ha) (NHB, 2022).

Nowadays, for the increasing flower production, nutrients are supplied through chemical fertilizers. The excessive use of synthetic chemical, such as fertilizers and pesticides, not only degrades soil physical, chemical and biological characteristics, which affects flower yield and quality. As a result, in modern floriculture noval approaches have been developed to achieve sufficient and sustainable yield with quality blooms. Utilizing plant bio-stimulants based on humic substances is one strategy for producing adequate and long-lasting high quality blooms. Humic acid is a promising natural resource that can be used to boost crop production (Nikbakht *et al.*, 2008). It is a naturally occurring polymeric organic molecule that plays crucial role in improving soil fertility and increases nutrients availability, enhancing plant growth, yield and decrease the harmful effect of stresses through various mechanisms inside the plants and soil (Moraditochaee, 2012). It is present in soil, peat, and lignite and is formed by the decomposition of organic material (Sharif *et al*., 2002). Furthermore, it has been reported that humic acid affects vegetative, flowering and yield parameters, which influences the overall economic returns for crop cultivation (Patil and Kumar, 2021). The application of humic acid in flower crops through foliar method is a great natural and organic technique to give soil and plants a concentrated dose of vital minerals, vitamins, and trace elements and stimulates plant growth harmones such as auxin and cytokinin, which support photosynthesis, nutrient metabolism, and stress resistance (Ampong *et al*., 2022). Numerous studies have reported the beneficial effects of humic acid on flowers crops. However, its impact on chrysanthemum growth and flowering under Bharsar climatic conditions remains underexplored. Understanding how humic acid affects the physiological and economic aspects of chrysanthemum cultivation in this specific environment could pave the way for long-term strategies that enhance productivity, while reducing environmental impact. Keeping all of this in mind, the current study aimed to investigate the effect of humic acid on chrysanthemum for growth, flowering and economic parameters in Uttarakhand temperate zone.

Materials and Methods

Experimental site and Propagation of planting material

The experiment site was, the Floriculture and Landscaping Block, College of Horticulture, Veer Chandra Singh Garhwali, Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal (Uttarakhand), which is situated at hills of Himalayas at latitude of 29°20' - 29°75' North and longitude of 78°10' - 78°80' East at an elevation of 1900 m amsl in the high-hills zone, served at the site of the field experiment for one growing seasons (June 2022 to February 2023) under naturally ventilated polyhouse condition. In general, the climate of this place represents the mild summer, higher precipitation and colder or severe cold throughout winter. Fig. 1 displays the meteorological data collected during the experiment.

At the experiment farm, four-week-old rooted healthy and diseased-free mother plants of chrysanthemum variety 'Garden Beauty' were selected and terminal cuttings of 5-7 cm length having 3-4 nodes were taken with the help of secateur. These cuttings were treated with Bavistin solution (0.1%) for 30 minutes and rooting harmones (NAA 500 ppm) by quick dip method prior to planting for better root germination, which future planted in pro-trays filled with the media containing Cocopeat + perlite (1:1 v/v). Under naturally ventilated polyhouse condition, one month old uniform sized rooted cutting having 3-4 leaf stage were selected and transplanted in raised bed of size 120 × 90 × 15 cm, respectively (L× B × H) at a spacing of 30 × 30 cm, accommodating 12 plants per bed. In order to prepare bed, the ploughing was done thoroughly up to a depth of 30 cm and well-rotted FYM (Farmyard Manure) @ 2.5

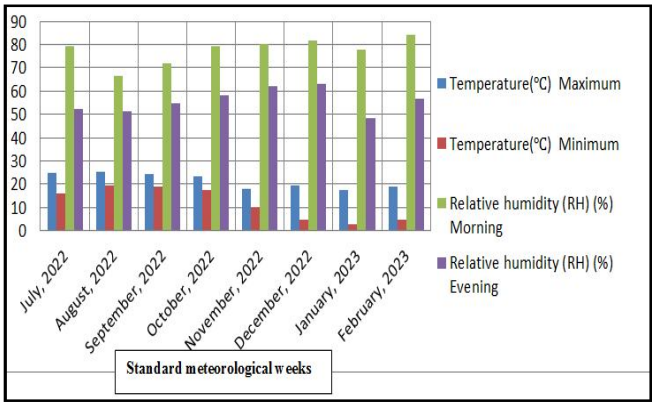

Fig. 1: Agrometerological data during the experimental period (July, 2022 – February, 2023).

Table 1: Effect of different concentrations of humic acid on vegetative parameters of chrysanthemum var. "Garden Beauty".

Treatments	Plant height (cm)	Number of Primary branches per plant	No. of leaves per plants	Plant Spread (cm)	Leaf area (cm^2)	No. of suckers per plant
T_1: Control	79.90	4.70	95.95	31.67	15.53	5.10
T_2: HA @ 0.2%	80.30	5.65	100.80	34.05	16.61	6.40
T_3: HA @ 0.4%	95.75	7.42	112.25	40.44	18.81	6.05
T_4: HA @ 0.6%	102.75	8.10	180.32	44.30	22.67	8.85
T_5: HA @ 0.8%	96.31	7.75	120.42	40.95	20.66	9.80
T_6: HA @ 1.0%	87.11	6.85	109.50	39.50	17.98	8.35
S.E. (d)	**3.40**	**0.53**	**2.92**	**1.91**	**0.97**	**0.85**
C.D. (0.05)	**7.32**	**1.15**	**6.29**	**4.11**	**2.10**	**1.83**
*Significant at 5% level of significance as compared to control						

kg/m^2 was incorporated into the soil prior to planting. The experiment farm had sandy loam soil with good drainage and optimum water retentation.

Experimental design and treatment application

The experiment was laid out on chrysanthemum variety 'Garden Beauty' in Randomized Complete Block Design (RCBD) with four replications, consisting of 6 treatments of different concentration of humic acid *viz.* (T_1: Control, T_2: 0.2%, T_3: 0.4%, T_4: 0.6%, T_5: 0.8% and T_6: 1.0%). The humic acid was purchased from the online site *i.e.*, Indian MART. It was the product of Tropical Agro System (India) Pvt. Ltd and was available in liquid form. Application of humic acid through foliar spray in whole plant from top to bottom was done by hand sprayer at the four different of 15, 30, 45 and 60 days interval during the experiment. Among the description of chrysanthemum varieties, 'Garden Beauty' is an open pollinated seedling of 'Flirt' released from PAU, Ludhiana. It is a tall spray type cultivar having large sized spoon type maroon flowers (Sindhu, 2019). Pinching practices was performed two times by removal of 2-3 cm of apical growth portion of the plants after 3 and 5 weeks of planting.

Vegetative and flowering attributes

For every replication and treatment, five plants were randomly selected and all the vegetative (plant height, number of primary branches per plant, number of leaves per plant, plant spread, Leaf area and Number of sucker per plant) and flowering parameters (days taken to first bud appearance, days taken to first flower opening, days taken to 50% flowering, flowering duration, flower longevity, spray length, flower diameter, number of cut sprays per plant, flowers per plant, flowers per m^2 and vase life) were recorded at the time of full blooming stage of plant.

Statistical analysis

The data obtained from different treatments during the research was statistically analysed using MS EXCEL, OPSTAT etc. The mean values of data were subjected to one-way analysis of variance (ANOVA) as per "Statistical procedures for Agriculture Research" by Gomez and Gomez (1984) for randomized completely block design (RCBD) and the treatments were compared at the 0.05% significance level.

Results

Effect of different concentrations of humic acid on vegetative parameters in chrysanthemum variety 'Garden Beauty'.

The results of the experiment demonstrate that application of different concentrations of humic acid through foliar method significantly enhanced the vegetative growth of chrysanthemum variety "Garden Beauty" as shown in Table 1. Among four humic acid concentrations, plants sprayed with 0.6% humic acid resulted in tallest plant height (102.75 cm), maximum number of primary branches per plants (8.10), number of leaves per plant (180.32), plant spread (44.30 cm) and leaf area (22.67 cm^2). Whereas, shortest plant height (79.90 cm), minimum number of primary branches per plants (4.70), number of leaves per plant (95.95), plant spread (31.67 cm) and leaf area (15.53 cm^2) were observed in plants without application of humic acid *i.e.* Control. However, plant sprayed with 0.8% humic acid produce more number of suckers per plant (9.80) while, it was observed produced less (5.10) in control treated plants. The results showed that all the treatment was found significantly superior as compare to control.

Effect of different concentrations of humic acid on flowering parameters in chrysanthemum variety 'Garden Beauty'.

According to the data tabulated in Table 2a, the chrysanthemum variety "Garden Beauty" was significant influenced by the different humic acid concentrations on all flowering parameters recorded during the experiment.

Table 2a: Effect of different concentrations of humic acid on flowering parameters of chrysanthemum var. "Garden Beauty".

Treatments	Days taken for first flower bud formation (days)	Days taken for first flower opening (days)	Number of days taken for 50% flowering (days)	Number of flower per plant	Number of flowers per plot	Number of cut sprays per plant
T_1: Control	67.80	99.60	113.50	68.60	761.80	12.55
T_2: HA @ 0.2%	67.45	99.55	112.00	69.70	775.46	13.85
T_3: HA @ 0.4%	67.20	99.55	110.25	78.00	866.20	17.75
T_4: HA @ 0.6%	64.85	94.50	104.50	89.00	988.42	21.25
T_5: HA @ 0.8%	64.90	94.75	106.00	76.25	846.99	17.05
T_6: HA @ 1.0%	66.70	95.55	106.50	70.45	782.40	14.80
S.E. (d)	**0.91**	**2.00**	**1.05**	**2.40**	**5.84**	**1.20**
C.D. (0.05)	**1.95**	**4.31**	**2.26**	**5.16**	**12.57**	**2.59**
*Significant at 5% level of significance as compared to control						

Among six humic acid concentration, early first flower bud formation (64.85 days), first flower opening (94.50 days), days taken for 50% flowering (104.50 days), maximum flowers per plant (89.00), flowers per plot (988.42) and maximum cut sprays per plant (21.25) was noticed under plants sprayed with 0.6% humic acid. Whereas, delayed in first flower bud formation (67.80 days), first flower opening (99.60 days), days taken for 50% flowering (113.50 days), minimum flowers per plant (68.60), flowers per plot (761.80) and cut sprays per plant (12.55) was observed under plants without application of humic acid served as control.

Furthermore, result emboided in Table 2b indicated that plant treated with 0.6% humic acid showed the maximum flower diameter (11.95 cm), spray length (59.29 cm) and vase life (14.50 days) while, minimum flower diameter (10.03 cm), spray length (47.32 cm) and vase life (11.60 days) was recorded in control plants. Whereas, prolonged duration of flowering (24.75 days) was recorded in plants treated with 0.4% humic acid and minimum (18.50 days) was observed in control plants. However, maximum flower longevity (19.90 days) was noticed under plants treated with 0.8% humic acid while, it was recorded minimum (10.55 days) in plants grown in control. The data showed that all the treatments were found significantly superior over control.

Table 2b: Effect of different concentrations of humic acid on flowering attributes of chrysanthemum var. "Garden Beauty".

Treatments	Flower dia-meter (cm)	Spray length (cm)	Flowe-ring duration (days)	Flower long-evity (days)	Vase life (days)
T_1: Control	10.03	47.32	18.50	10.55	11.60
T_2: HA @ 0.2%	10.78	50.51	19.25	13.50	12.00
T_3: HA @ 0.4%	11.05	53.41	24.75	14.20	13.55
T_4: HA @ 0.6%	11.95	59.29	22.15	15.10	14.50
T_5: HA @ 0.8%	11.44	55.53	21.90	15.90	13.90
T_6: HA @ 1.0%	11.29	55.05	21.80	14.70	13.85
S.E. (d)	**0.42**	**1.33**	**1.85**	**0.66**	**0.76**
C.D. (0.05)	**0.90**	**2.86**	**3.99**	**1.42**	**1.63**
*Significant at 5% level of significance as compared to control					

Effect of different concentrations of humic acid on economics of chrysanthemum variety 'Garden Beauty'.

Data depicted in Table 3 showed the significant effect of different concentration of humic acid on economics of chrysanthemum variety "Garden Beauty". Plants which were treated with treatment T_6 (1.0 % humic acid) resulted in highest cost of cultivation (25,838.05 Rs/100m^2) while, lowest (24,912.13 Rs/100m^2) was recorded in control (T_1). Data also showed that maximum gross return (53,111.00 Rs/100m^2), Net return (27,643.46 Rs/100m^2) and cost benefit ratio (1.09) were noticed under plants treated with treatment T_4 (0.6% humic acid). However, minimum gross return (30,944.00 Rs/100m^2), Net return (6,032.31 Rs/100m^2) and cost benefit ratio (024) were recorded in plants without application of humic acid served as control.

Discussion

Effect of different concentrations of humic acid on vegetative parameters in chrysanthemum variety 'Garden Beauty'

The results showed that the vegetative growth of chrysanthemum var. 'Garden Beauty' was significantly enhanced by foliar application of humic acid @ 0.6%. The reason for increased plant height under this treatment may be that humic acid acts as a hormone-like substance that increases endogenous auxin and cytokinins within the plant (Gawade *et al.*, 2019). Due to this, affects assimilate production and causes increased in cell elongation and cell division, thus plant height increased. Khudair and Albbas (2021) reported that plants sprayed

Table 3: Effect of different concentrations of humic acid on economics of chrysanthemum var. "Garden Beauty".

Treatments	Cost of cultivation (Rs/100m²)	Gross return (Rs/100m²) (Flowers + Suckers)	Net return (Rs/100m²)	Cost: Benefit ratio
T_1: Control	24,912.13	30,944.00	6,032.31	0.24
T_2: HA @ 0.2%	25,097.25	36,722.00	11,624.97	0.46
T_3: HA @ 0.4%	25,282.45	39,889.00	14.606.44	0.58
T_4: HA @ 0.6%	25,467.65	53,111.00	27,643.46	1.09
T_5: HA @ 0.8%	25,652.85	51,611.00	25,958.26	1.01
T_6: HA @ 1.0%	25,838.05	44,111.00	18,273.06	0.71

with humic acid significantly increased the plant height of *Gazania splendes*. Similarly, the positive effect of humic acid on plant height has been also reported by Mohammadipour *et al*., (2012) in *Calendula officinalis*, Bashir *et al.*, (2016) in *Gladiolus grandiflorus* and Boogar *et al*., (2014) in *Petunia hybrida.* Significant increase in number of primary branches and leaves per plant could be attributes to the breaking of apical dominance, which promotes greater axillary bud sprouting. Mayi *et al*., (2014) stated that humic acid treated plants significantly enhanced the number of primary branches per plant. The reason for the increase in number of leaves per plant and leaf area might be that humic acid stimulates the production of hormones like gibberellins, which encourage the formation, elongation and expension of leaves. This increases the level of chlorophyll content, which accelerates the rate of photosynthesis and produced a greater number of leaves with larger leaf area in plants. Vidya *et al*., (2022) reported that humic acid significantly increased the number of leaves per plant in *Callistephus chinensis*. Similarly, increased in leaf area of *Zinnia elegans* with the application of humic acid was reported by Khan *et al*., (2020). The above results are corroborated with the finding of Palanisamy *et al*., (2015) in *Gerbera jamesonii*, Hasan (2019) in *Calendula officinalis* and Ahmad *et al*., (2013) in *Gladiolus grandiflorus*. The increased plant spread might be related to greater vegetative growth of plant. The number of branches and leaves per plant increased, resulting in denser, compact and bushy growth, contributing to a more spreading plant structure. Vidya *et al*., (2022) stated that foliar spraying of humic acid considerably enhanced plant spread in *Callistephus chinensis*. Similar studies have been reported by Praveen *et al*., (2021) in *Rosa spp*., Ghosh *et al*., (2022) in *Tagetes erecta*. Furthermore, increased in number of suckers per plant was noticed under plant treated with humic acid @ 0.8%. This could be attributed to be better availability and uptake of nutrients which could have results enhanced vegetative growth and hence improved number of suckers. These results are in harmony with those of Manda *et al*., (2014) in *Spathiphyllum wallisii*; Patil and Kumar (2021) in *Dendranthema grandiflora*.

Effect of different concentrations of humic acid on flowering parameters in chrysanthemum variety 'Garden Beauty'

According to the findings, a foliar spray of humic acid @ 0.6% significantly enhanced flowering parameters in chrysanthemum var. 'Garden Beauty'. The reason for earliness in days taken for first bud appearance, flower opening and early days for 50% flowering might be due to humic acid helps in enhancing nutrient uptake, stimulating hormonal activity and improving the photosynthesis. This factor promotes early vegetative growth in plants, which leads to earlier flower bud formation and flower opening. Vidya *et al*., (2022) stated that plant treated with humic acid significantly promotes early flower bud appearance, first flower opening and early days for 50% flowering in *Callistephus chinensis*. Mohammed *et al*., (2020) reported that earliness in flowering and bud formation was resulted humic acid treated plants in *Hibiscus sabdariffa*. The present results are supported by findings of Keisam *et al*., (2014) in *Gladiolus grandiflorus*, Memon *et al*., (2014) in *Phlox paniculata* and Ali *et al*., (2015) in *Tulipa gesneriana*. Production of a greater number of cut sprays per plant, flowers per plant and per plot could be attributed to humic acid treatment, which could have resulted in a significantly increase in vegetative growth, which in turn created more photosynthates, which were most likely channeled towards increased floral production in plants. Shrikant and Jawaharlal (2014) found that plants treated with humic acid produced more flowers per plant and plot in *Gerbera jamesonii*. Similar studies have been reported by Mohammadipour *et al*., (2012) in *Calendula officinalis*, Boogar *et al*., (2014) in *Petunia hybrida* and Esringu *et al*., (2015) in *Impatiens walleriana*. Increased in flower diameter and spike length might be due to application of humic acid enhanced the nutrient intake, increased photosynthesis and improved nutrient translocation to flowers, which could attribute to increased floral diameter and spray length. This idea goes in parallel with those of Thakur *et al*., (2013) in *Helianthus annuus*, Memon *et al*., (2014) in *Zinnia elegans*, Bashir *et al*., (2016) in *Gladiolus grandiflorus* and Khudair and Albbas (2021) in *Gazania splendens*. Whereas, plants treated with humic acid @ 0.4% were resulted in prolonged duration of flowering. This might

be due to presence of humates which facilitated nutrient uptake and improved soil structure by humic acid, leads in prolonged duration of flowering in plants. Bolagam and Natarajan (2019) reported that plants sprayed with humic acid 0.4% display prolong duration of flowering *Gladiolus grandiflorus*. The above results are corroborated with the findings of Memon *et al*., (2014) in *Petunia milliflora* and Memon and Khetran (2014) in *Antirrhinum majus*. The data also show that foliar application of humic acid @ 0.8% significantly improve flower longevity in plant, which could be because humic acid contain cytokinins and auxin, which may have improved antioxidant levels and resistance to senescence thus, prolonged flower longevity. Gawade *et al*., (2019) in *Dendranthema grandiflora* reported that foliar application of humic acid resulted in prolonged flower longevity. Positive effect of humic acid was also reported by Hasan (2019) in *Calendula officinalis* and Shrikant and Jawaharlal (2014) in *Gerbera jamesonii*.

Effect of different concentrations of humic acid on economics in chrysanthemum variety 'Garden Beauty'

Profit depends not only on the productivity of the crop but also the quality of the produce in association with the competitive price in the market. Plants sprayed with humic acid @ 0.6% results best among all the concentrations. This could be due to fact that increased in number of cut sprays per plant, number of flowers per plant and per plot as well as number of suckers per plant respectively, which resulted in increase in gross return, net return and cost benefit ratio. Where, highest cost of cultivation was found in plants treated with humic acid @ 1% which could be attributed that highest price of humic acid was used in this treatment as compared other treatments. Similar findings have been reported by Swathima (2009) in *Tagetes erecta*, Archana (2018) in *Polianthus tuberosa*, Bolagam and Natarajan (2019) in *Gladiolus grandiflorus*; Patil and Kumar (2021) in *Dendranthema grandiflora*.

Conclusion

The study conclusively revealed that foliar application of humic acid @ 0.6% significantly enhanced the vegetative, flowering characteristics and economics returns of chrysanthemum var. 'Garden beauty' as compared to the control under naturally ventilated polyhouse in temperate region of Uttarakhand.

Future recommendations

The objective of future study should be focus on optimizing humic acid concentrations, particularly investigating the range between 0.6% and 0.8%, to balance vegetative growth and flowering in chrysanthemum. Long-term trails are essential to evaluate cumulative and residual effects, while economic feasibility should be tested across various varieties. Exploring interaction studies with biofertilizers or micronutrients and alternative application methods, like soil drenching can further enhance chrysanthemum productions efficiency and profitability.

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