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RESPONSE OF CATECHOL, TRIACONTANOL, NAA AND GIBBERELLIC ACID ON GROWTH AND YIELD OF CHRYSANTHEMUM (*CHRYSANTHEMUM CORONARIUM*) CV. MARGRATE

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ABSTRACT

Chrysanthemum (*Chrysanthemum coronarium* L.) is an economically important annual ornamental species cultivated for its decorative, culinary, and commercial value. Despite its wide adaptability, achieving optimum growth, early flowering, and higher flower yield under field conditions remains a major challenge. The present study was undertaken to assess the influence of selected plant growth regulators on vegetative growth, flowering behaviour, and yield attributes of *C. coronarium* cv. Margrate. The experiment was conducted at the Centre of Agricultural Education, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, following a randomized block design with three replications and eight treatments. Foliar applications of triacontanol, gibberellic acid, catechol and naphthalene acetic acid (NAA), individually and in combinations, were applied at a concentration of 100 ppm. The results revealed significant differences among treatments for all recorded parameters. Application of catechol at 100 ppm resulted in superior vegetative growth in terms of plant height, plant spread, and leaf production, along with enhanced flower diameter, earlier bud and flower initiation, and the highest flower yield per plant, per plot, and per hectare. Triacontanol at 100 ppm and the combination of Triacontanol + GA_3 at 100 ppm each also showed substantial improvements over the control. The positive response observed under catechol treatment may be attributed to its role in regulating endogenous hormones, enhancing photosynthetic efficiency, improving nutrient uptake, and strengthening antioxidant activity, which collectively favor reproductive development and yield. The findings of this study indicate that targeted foliar application of catechol, triacontanol, and GA_3 can be effectively employed to improve growth performance, flowering earliness, and flower productivity of *Chrysanthemum coronarium* under field conditions, thereby supporting it's for commercial cultivation.
Keywords: Catechol, *Chrysanthemum* flower yield, foliar application, gibberellic acid (GA_3) and triacontanol.

Introduction

Chrysanthemum coronarium L., commonly known as annual chrysanthemum, crown daisy, garland chrysanthemum, or edible chrysanthemum, is an aromatic annual herb belonging to the family Asteraceae. The species is native to the Mediterranean region and is widely distributed across Europe, North Africa, and Asia (Sharma *et al.*, 2015). It is valued both for its ornamental appeal and its distinctive flavour, which makes it suitable for culinary and decorative purposes (Jena & Mohanty, 2021). Recently reclassified as *Glebionis coronaria*, the crop is cultivated commercially for the production of both cut and loose flowers.

In India, annual chrysanthemum is predominantly grown as a winter season crop in several states, including Maharashtra, Karnataka, Bihar, Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, and West Bengal. The cultivar “Cherry Gold” is especially popular in West Bengal and Odisha, where the plant is also grown ornamentally in garden beds and borders (Mohanty *et al.,* 2023). Owing to its wide adaptability and multiple uses, *C. coronarium* has attracted considerable attention in floriculture and phytochemical research, focusing on genetic improvement, value addition, and sustainable cultivation practices (Belhachat *et al.,* 2023).

The species produces large, attractive blooms suitable for garland making and decorative purposes during cultural and religious functions. Additionally, *C. coronarium* has been reported to act as a companion plant that helps protect neighbouring crops from caterpillar infestation, while root exudates have shown potential nematicidal activity in soil (Sharma *et al.,* 2015; Misra *et al.,* 2002).

With technological advancement and modernization in floriculture, growers increasingly focus on achieving ideal plant architecture, superior flower quality, and enhanced productivity in flower crops. To attain these objectives, various plant growth regulators are being utilized to manipulate vegetative growth and flowering behaviour in chrysanthemum, enabling the production of compact plants and the regulation of growth rates according to market requirements. In recent years, considerable attention has been given to plant growth regulation as a vital approach complementary to genetic and environmental factors for improving plant growth, yield, and quality through the judicious application of growth-promoting chemicals (Choudhari *et al.,* 2018; Ara *et al.,* 2023). Hence, the present investigation was undertaken to optimise flower production and regulate its timing to meet fluctuating market demands.

Despite its commercial importance, maximising the yield and ornamental quality of *Chrysanthemum coronarium* L. remains challenging due to several agronomic and physiological constraints. Conventional horticultural practices often fail to achieve the desired balance between flower quality and quantity, thereby necessitating the adoption of innovative cultivation strategies. Among the major constraints, soil infertility significantly limits crop productivity in developing countries, particularly affecting resource-poor farmers (Islam *et al.,* 2025). One promising approach to overcome these limitations is the use of plant growth regulators (PGRs) a class of organic compounds, either natural or synthetic, that modulate various physiological and biochemical processes in plants. PGRs such as triacontanol, gibberellic acid (GA_3), catechol, and naphthalene acetic acid (NAA), along with newer synthetic analogues, have emerged as vital tools in modern horticulture for manipulating plant architecture, enhancing flowering and fruiting, and improving stress tolerance (Sainath & Meena, 2012; Ara *et al.,* 2022).

Among different plant growth regulators, triacontanol is a long-chain primary alcohol that enhances plant growth by stimulating cell division and differentiation, resulting in increased root and shoot biomass, as well as improved photosynthetic efficiency, enzymatic activity, and nutrient uptake (Verma *et al.,* 2022). Gibberellic acid (GA_3) plays a crucial role in promoting stem elongation, increasing flower size, and improving the overall flowering quality of ornamental plants (Ara *et al.,* 2022; Choudhari *et al.,* 2018). Catechol, a simple phenolic compound, has been reported to induce root initiation and shoot elongation by modulating redox activity and activating oxidative enzymes such as polyphenol oxidase and peroxidase (De Klerk *et al.,* 2011). Similarly, naphthalene acetic acid (NAA), a synthetic auxin, is widely used to promote flowering, reduce flower bud drop, and enhance cell division, enlargement, and elongation in apical tissues, thereby improving overall plant growth and productivity (Ara *et al.,* 2022).

Material and Methods

Experimental site

The present experiment was conducted at Centre of Agricultural Education, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh (UP) India. The experiment site was situated at 27.88 N latitude, 78.20 E longitudes and above the 178-metre mean sea level. Aligarh is situated in the middle portion of doab or the land between the Ganga and Yamuna River.

Planting material and planting

The seeds of *Chrysanthemum coronarium* L.cv. Margrate were procured from the Indian Agricultural Research Institute (IARI), New Delhi. Raised beds (3×1m) sizes were prepared in a weed-free field, and seeds were sown. Light irrigation was provided morning and evening to ensure proper seedling establishment.The field was thoroughly ploughed, leveled, and enriched with 20 tons/ha of well-decomposed FYM. Beds (1.35 × 1.35 m) were prepared, and a basal dose of NPK (120:50:50 kg/ha) was applied before transplanting. Healthy chrysanthemum cv. Margrate seedlings were transplanted at 30 × 30 cm spacing for production.

Experimental design and layout

The experiment was laid out in completely randomized block design with three replications and eight treatments. The comparative performance was evaluated for nine quantitative traits, namely: plant height (cm), plant spread (cm), number of leaves per plant, diameter of flower (cm), days to first bud initiation, days to first flower initiation, flower yield per plant (g), flower yield per plot (kg), and flower yield per ha (q). The details of the experimental treatments are presented in Table 1.

Table 1 : Details of treatment of the experiment

S. No.	Treatments	Details of treatments
1.	T_1	Control
2.	T_2	Triacontanol @ 100ppm
3.	T_3	GA_3 @ 100ppm
4.	T_4	Catechol @ 100ppm
5.	T_5	NAA @ 100ppm
6.	T_6	Triacontanol @ 100ppm + GA3 @ 100ppm
7.	T_7	GA3 @ 100ppm + Catechol @ 100 ppm
8.	T_8	Catechol @ 100ppm + NAA @ 100 ppm

Preparation of plant growth regulator and application

Plant growth regulators (Triacontanol, GA_3, Catechol, and NAA) were prepared according to the treatment. Each PGR was applied at a concentration of 100 ppm. To prepare a 100 ppm solution of each PGR, 1 mL of the respective stock solution were diluted with deionized water to make a final volume of one liter. The solution was thoroughly mixed using a glass rod to ensure homogeneity and applied to the plants as a foliar spray.

Result and Discussion

The result of experiment is given under (Table 2) foliar application of Catechol, NAA Triacontanol and Gibberellic acid were significantly influenced all the parameters of the experiment.

Plant Height (cm)

Plant height exhibited significant variation in response to different plant growth regulators (PGRs) at both 30 and 60 days after transplanting (Table 2). At 30 DAT, the highest plant height (75.43 cm) was recorded under T_4 Catechol @ 100 ppm, followed by T_5 NAA @ 100 ppm (72.43 cm) and the combined treatment of T_6 Triacontanol + GA_3 @ 100 ppm each (72.06 cm). The lowest height (51.08 cm) was obtained in the control. A similar trend persisted at 60 days after transplanting, where Catechol @ 100 ppm again produced the tallest plants (77.63 cm), significantly surpassing GA_3 (72.86 cm) and NAA (74.76 cm) treatments. The pronounced enhancement in plant height with Catechol application could be attributed to its phenolic nature, which likely modulates endogenous hormone levels, promotes cell elongation, and enhances photosynthetic activity and nutrient uptake-ultimately leading to vigorous vegetative growth (Masroor *et al.*, 2023). Likewise, NAA and the combined treatment of Triacontanol + GA_3 effectively stimulated stem elongation through auxin- and gibberellin-mediated processes that promote cell division and elongation (Adam, 2025; Idrees, 2010). Furthermore, the antioxidant potential of Catechol may contribute to mitigating oxidative stress, thereby sustaining active vegetative development (De Klerk *et al.*, 2011). Overall, the Catechol @ 100 ppm proved to be the most effective treatment for promoting stem elongation, underscoring its multifaceted role in hormonal regulation, metabolic enhancement, and stress resilience.

Plant Spread (cm)

Foliar application of different PGRs significantly influenced plant spread in both north–south (N-S) and east–west (E-W) orientations at 30 and 60 days after transplanting (Table 2). The maximum plant spread was achieved with T_4 Catechol @ 100 ppm, which recorded 49.41 cm (N-S) and 44.40 cm (E-W) at 30 days after transplanting, increasing further to 52.37 cm (N-S) and 49.87 cm (E-W) at 60. This was closely followed by T_2 Triacontanol @ 100 ppm and the combined treatment of T_6 Triacontanol + GA_3 @ 100 ppm each. In contrast, the minimum spread was noted in the control, with 40.22 cm (N-S) and 39.43 cm (E-W). The superior plant spread observed with T_4 Catechol @ 100 ppm can be attributed to its potential role in modulating the auxin-cytokinin balance, which stimulates lateral bud outgrowth and enhances photosynthetic performance (Masroor *et al.,* 2023). Triacontanol, on the other hand, has been reported to elevate chlorophyll synthesis and improve assimilate translocation, thereby facilitating greater canopy expansion and vegetative vigor (Naeem *et al.,* 2012). Overall, the findings suggest that T_4 Catechol @ 100 ppm is most effective in promoting lateral growth and canopy development, likely through its integrated effects on hormonal regulation and photosynthetic efficiency.

Number of Leaves per Plant (30 and 60 DAT)

Foliar application of various PGrs significantly affected the number of leaves per plant at both 30 and 60 days after transplanting (Table 2). The maximum mean leaf count was obtained with T_4 Catechol @ 100 ppm, producing 19.43 and 19.47 leaves at 30 and 60, respectively. This was followed by T_3 GA_3 @ 100 ppm (18.33 and 18.67) and the combined treatment of T_7 GA_3+ Catechol @ 100 ppm each (18.93 and 19.27). The minimum number of leaves was recorded in the control (13.77 and 14.37). The significant increase in leaf number observed under Catechol and GA_3treatments can be attributed to their combined influence on physiological and biochemical processes that promote vegetative development. Catechol, being a phenolic compound, is known to enhance endogenous auxin and cytokinin activity, thereby stimulating cell division, leaf initiation, and overall shoot growth (Masroor *et al.,* 2023). Similarly, GA_3 facilitates cell elongation, chlorophyll synthesis, and meristematic activity, which collectively contribute to greater leaf formation and improved photosynthetic performance (Sajid *et al.,* 2016). The moderate enhancement observed with T_2 Triacontanol @ 100 ppm (17.36 and 17.66) further supports its role in promoting photosynthetic efficiency, nutrient absorption, and enzymatic activity (Naeem *et al.,* 2012). In summary, foliar application of Catechol, GA_3, and their combinations proved most effective in stimulating leaf production, emphasizing their potential to accelerate vegetative growth and improve physiological efficiency under field conditions.

Flower Diameter (cm)

Foliar application of different plant growth regulators exerted a significant influence on flower diameter (Table 2). The largest flower diameter was recorded with T_4 Catechol @ 100 ppm (5.87 cm), followed by T_2 Triacontanol @ 100 ppm (5.33 cm) and GA_3 @ 100 ppm (4.77 cm). The control produced the smallest flowers (4.20 cm). Combination treatments, including T_6 Triacontanol + GA_3 @ 100 ppm each (5.13 cm) and T_7 GA_3 + Catechol @ 100 ppm each (4.97 cm), also resulted in significant improvement over the control. The superior flower diameter achieved under T_1 Catechol @ 100 ppm may be attributed to its phenolic composition, which enhances hormonal regulation, antioxidant defense, and cell division-ultimately promoting cellular expansion in floral tissues (Masroor *et al.,* 2023). Triacontanol, on the other hand, has been reported to enhance photosynthetic performance, carbohydrate metabolism, and assimilate translocation, which collectively contribute to the development of larger and higher-quality flowers (Naeem *et al.,* 2012). Likewise, gibberellic acid (GA_3) is known to stimulate cell elongation and floral organ differentiation, thereby increasing flower size, as previously observed in *Tagetes erecta* (Kanwar & Khandelwal, 2013). In general, the combined use of these growth regulators demonstrated a synergistic effect, markedly enhancing flower diameter relative to the untreated control. This suggests their substantial potential for improving floral quality and productivity under field conditions.

Days to first bud initiation

Foliar application of various plant growth regulators had a significant effect on the days to first bud initiation in *Chrysanthemum coronarium* (Table 2). The earliest bud initiation was observed with T_1 Catechol @ 100 ppm, occurring at 47.67 days, followed by T_7 GA_3 + Catechol @ 100 ppm each at 52.33 days and T_6 Triacontanol + GA_3 @ 100 ppm each at 53.33 days. Moderate responses were recorded with T_2 Triacontanol @ 100 ppm (55.33 days) and T_3 GA_3 @ 100 ppm (56.33 days), while delayed bud initiation was noted under T_5 NAA @ 100 ppm (58.33 days) and T_8 Catechol + NAA @ 100 ppm each (57.67 days). The control exhibited the longest duration to bud initiation (61.33 days). The advancement in bud initiation with T_4 Catechol @ 100 ppm may be attributed to its phenolic nature, which enhances cellular metabolism, hormonal signalling, and the transition from vegetative to reproductive growth phases (Masroor *et al.,* 2023). The combined treatments of GA_3 + Catechol and Triacontanol + GA_3 further promoted early bud development by improving meristematic activity and hormonal responsiveness. Likewise, GA_3 alone effectively reduced the time to bud initiation through its role in stimulating cell division, elongation, and floral induction (Ara *et al.,* 2022). In summary, the application of Catechol and GA_3, either individually or in combination, proved highly effective in reducing the vegetative phase and inducing earlier flowering in *Chrysanthemum coronarium*, highlighting their potential for improving crop earliness and reproductive performance.

Days to first flower initiation

Foliar application of various plant growth regulators had a significant impact on the number of days required for first flower initiation in *Chrysanthemum coronarium* (Table 2). The earliest flower initiation was observed with T_4 Catechol @ 100 ppm, which recorded 57.67 days, followed by T_7 GA_3 + Catechol @ 100 ppm each with 59.67 days and T_6 Triacontanol + GA_3 @ 100 ppm each with 64.33 days. Moderate effects were noted under T_2 Triacontanol @ 100 ppm (65.67 days) and T_3 GA_3 @ 100 ppm (67.33 days), whereas delayed flowering was observed in T_5 NAA @ 100 ppm (68.33 days), T_8 Catechol + NAA @ 100 ppm each (68.33 days), and the control (72.33 days). The reduction in days to flower initiation under Catechol and GA_3 treatments can be attributed to their synergistic effects on hormonal balance, cellular metabolism, and reproductive transition. Catechol, owing to its phenolic characteristics, may enhance hormonal signalling pathways and promote metabolic activities essential for floral induction, while GA_3stimulates cell division and elongation, accelerating floral organ development (Ara *et al.,* 2022). The combined treatment of GA_3+ Catechol further amplified these effects, indicating improved coordination of physiological and biochemical processes leading to earlier flowering. Generally, the application of Catechol and GA_3, individually or in combination, proved most effective in advancing floral initiation in *Chrysanthemum coronarium,* emphasizing their potential to promote timely flowering and improve reproductive efficiency under field conditions.

Flower yield per plant (g)

Foliar application of different PGRs significantly affected flower yield per plant in *Chrysanthemum coronarium* (Table 2). The maximum flower yield was obtained with T_4 Catechol @ 100 ppm (228.33 g), followed by T_2 Triacontanol @ 100 ppm (207.22 g) and the combined treatment of T_6 Triacontanol + GA_3 @ 100 ppm each (192.22 g). These treatments exhibited a pronounced promotive effect on floral productivity through enhanced nutrient uptake, photosynthetic performance, and reproductive development. The combination of T_7 GA_3+ Catechol @ 100 ppm each also produced a favourable response (185.00 g), while the lowest yield was recorded in the control (130.55 g). The superior yield performance under Catechol, Triacontanol, and GA_3treatments may be attributed to their roles in enhancing physiological and biochemical processes such as antioxidant defence, hormonal regulation, and assimilate partitioning (Misra *et al.,* 2023). Additionally, their stimulatory effects on cell division and elongation promote improved floral initiation and development, resulting in higher yield (Acharya, 2021). Generally, the enhanced yield under Catechol, Triacontanol, and GA_3 treatments reflects their integrated influence on metabolic activity, hormonal modulation, and source–sink efficiency, highlighting their effectiveness in improving the floral productivity of *Chrysanthemum coronarium* under field conditions.

Flower yield per plot (kg)

Foliar application of various plant growth regulators (PGRs) significantly influenced flower yield per plot in *Chrysanthemum coronarium* (Table 2). The maximum flower yield was achieved with T_4 Catechol @ 100 ppm, producing 1.73 kg of flowers per plot, followed by T_2 Triacontanol @ 100 ppm (1.58 kg) and the combined treatment of T_6 Triacontanol + GA_3 @ 100 ppm each (1.54 kg). These findings highlight the pronounced promotive effects of Catechol and Triacontanol on reproductive performance, likely attributed to enhanced nutrient assimilation, increased photosynthetic activity, and improved translocation of assimilates toward developing floral structures. The efficacy of Catechol observed in this study corroborates the findings of Masroor *et al.* (2023), who reported that foliar application of catechol enhanced growth and yield in *Cymbopogon flexuosus* (lemongrass). Similarly, Verma (2022) demonstrated that Triacontanol application increased chlorophyll concentration, biomass accumulation, and overall productivity across various crops. GA_3 treatments (1.40 kg) also contributed to yield improvement, consistent with Ara *et al.* (2023), who reported that GA_3 promotes flowering in chrysanthemum by stimulating cell division, elongation, and floral differentiation. Conversely, NAA-based treatments (1.22 kg) were comparatively less effective, likely because auxins primarily promote vegetative rather than reproductive growth. Overall, Catechol, Triacontanol, and GA_3 emerged as the most effective PGRs for enhancing floral yield in *Chrysanthemum coronarium*. Their combined influence on nutrient dynamics, hormonal regulation, and metabolic efficiency underscores the potential of targeted PGR application to optimize flowering and yield under field conditions.

Flower yield ha^{-1}

Foliar application of different PGRs significantly affected flower yield per hectare in *Chrysanthemum coronarium* (Table 2). The maximum yield was recorded with T_4 Catechol @ 100 ppm (8.66 t ha^{-1}), followed by T_2 Triacontanol @ 100 ppm (7.90 t ha^{-1})

and the combined treatment of T_6 Triacontanol + GA_3 @ 100 ppm each (7.73 t ha^{-1}). Moderate yield responses were observed under GA_3 treatments (6.70 t ha^{-1}; 7.03 t ha^{-1}), whereas the lowest yields were obtained with NAA-based treatments (6.10 t ha^{-1} and 6.06 t ha^{-1}). The superior performance of Catechol may be attributed to its phenolic nature, which enhances nutrient uptake, photosynthetic efficiency, and antioxidant activity factors that collectively improve assimilate partitioning toward floral structures. Similar phenolic-mediated growth and yield enhancements following foliar application have been reported by Masroor *et al*. (2023). The increased productivity under Triacontanol treatments aligns with Verma (2022), who demonstrated that this PGR enhances chlorophyll content, photosynthetic rate, and carbohydrate metabolism, thereby supporting higher biomass and yield accumulation. Likewise, GA_3 mediated stimulation of cell division, elongation, and flowering, is well documented in chrysanthemum and other related ornamentals (Ara *et al.,* 2023). In summary, targeted foliar application of Catechol, Triacontanol, and GA_3 substantially improved flower yield in *Chrysanthemum coronarium*. These findings emphasize the potential of integrating specific PGRs into crop management practices to enhance physiological efficiency, reproductive performance, and commercial flower production under field conditions.

Table 2: Effect treatments on growth, flowering and yield attributes in *Chrysanthemum coronarium* L. cv. Margrate.

Treatments	**Plant height (cm)**		**Plant spread (cm)**				**No. of leaves**		**Flower diameter (cm)**	**Days to first bud initiation**	**Days to first flower initiation**	**Flower yield/ plant (g)**	**Flower yield/plot (g)**	**Flower yield/ hectare (tons)**
			E-W		**N-S**									
	30 Days	**60 Days**	**30 Days**	**60 Days**	**30 Days**	**60 Days**	**30 Days**	**60 Days**						
T_1	51.08	51.90	36.27	39.43	40.26	40.22	13.76	14.36	4.20	61.33	47.66	130.55	1.02	5.13
T_2	63.96	66.96	41.89	47.86	48.3	49.53	17.36	17.66	5.33	55.33	55.33	207.22	1.58	7.90
T_3	70.83	72.86	39.37	44.53	43.12	46.13	18.33	18.66	4.76	56.33	56.33	177.22	1.34	6.70
T_4	75.43	77.63	44.40	49.86	49.41	52.36	19.43	19.46	5.86	47.66	61.33	228.33	1.73	8.66
T_5	72.43	74.76	42.17	44.63	43.43	46.73	16.76	17.36	4.61	58.33	58.33	162.22	1.22	6.10
T_6	72.06	74.86	44.08	47.42	44.10	47.16	15.12	15.61	5.13	53.33	53.33	192.22	1.54	7.73
T_7	71.83	74.33	42.58	40.91	41.37	47.37	18.93	19.26	4.96	52.33	52.33	185	1.40	7.03
T_8	67.76	70.06	39.42	41.04	40.61	43.16	15.16	16.03	4.33	57.66	57.66	158.33	1.21	6.06
C.D.	**10.98**	**10.73**	**7.78**	**8.46**	**5.55**	**5.63**	**13.76**	**14.36**	**4.20**	**1.93**	**1.93**	**7.52**	**0.04**	**0.22**
SE(m)	**3.58**	**3.50**	**7.78**	**3.00**	**1.81**	**2.31**	**17.36**	**17.66**	**5.33**	**0.63**	**0.63**	**2.45**	**0.015**	**0.07**

Conclusion

Foliar application of plant growth regulators significantly enhanced the vegetative growth, flowering, and yield of *Chrysanthemum coronarium* L. cv. Margrate. Catechol @ 100 ppm was the most effective, followed by Triacontanol @ 100 ppm and Triacontanol + GA_3@ 100 ppm each. The superior performance of Catechol may be due to its role in enhancing hormonal balance, photosynthetic efficiency, and nutrient uptake. Among all the treatments, the use of Catechol, Triacontanol, and GA_3 proved effective in improving growth, earliness, and flower yield, indicating their potential for enhancing commercial chrysanthemum production.

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