Agriculture Association of Textile Chemical and Critical Reviews Journal (2025) 760-768

AATCC Review

16 July 2025: Received
06 September 2025: Revised
13 September 2025: Accepted
12 October 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article **Open Access**

Optimizing off-season flower production in *chrysanthemum* cv. Bidhan Shweta by synergistic effects of pinching and artificial short days

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ABSTRACT

Chrysanthemum, being a short-day plant, has a limited flowering period in the subtropical climate of North India, restricting its year-round production. Therefore, the current study was initiated to explore the effects of photoperiod manipulation and pinching strategies on the off-season production of this specific genotype. The experiment was laid out in a Completely Randomized Design with nine treatment combinations comprising three photoperiodic conditions (natural, artificial short days from April, artificial short days from June) with three pinching levels (no pinch, single and double). Results suggested that treatment T_4 (Artificial short days from April + no pinch) proved to be most effective for early flowering, as it took the least number of days for flower bud initiation at 74.56 days and 100% flowering at 122.12 days. But this earliness in flowering compromised the plant's aesthetic pot mum quality, resulting in a reduced number of branches (2.60), the minimum number of flowers per plant (22.07), and the smallest flower size (4.32 cm). Whereas, treatment T_3 (Natural photoperiod + double pinch) noticeably delayed flowering (192.82 days) but excelled in quality pot plant attributes like number of branches (7.65), maximum plant spread (33.94 cm), number of flowers per plant (64.41) and largest flower size (6.76 cm). The study concludes that the choice of treatment depends upon the grower's specific objective. For those who want early, off-season flowering to secure higher market prices, treatment T_4 is the best option. Contrary, if the objective is to produce aesthetically appealing quality pot mums for the main season, then treatment T_3 is recommended.

Keywords: *Pinching, earliness, short day, pot mum, production scheduling, apical dominance, chrysanthemum, controlled photoperiod, natural photoperiod, lateral shoots, photoperiodic manipulation, pot plant.*

Introduction

Chrysanthemum, a significant flower crop belonging to the Asteraceae family is native to the northern hemisphere, primarily Europe and Asia (1). It holds the status of national flower of Japan and is commonly known as '*Guldaudi*' in India and 'Glory of the East' or 'mum' in the United States. There is hardly any other garden flower that exhibits such a diverse and aesthetically pleasing array of colours and flower forms. Plants that have dwarf stature, attractive foliage, long or repeated flowering duration and are resistant to root bound are ideal for pot culture. But Chrysanthemum prefers to be the most desirable pot plant not only due to these qualities but also because of its ability to respond to off-season flower production. Being a short-day plant, the natural production season of chrysanthemum is restricted to a limited period of the year. However, through environmental manipulations, year-round flower production is achievable. In the subtropical climate of North India, chrysanthemum flowering occurs from October to December. This limited flowering period presents a significant obstacle to the commercialization of the crop in this region. Chrysanthemum thrives in cooler climates, requiring daytime temperatures of 20-28°C and nighttime temperatures of 15-20°C for flower bud initiation (). Due to its short-day nature, it cannot form flower buds when the day length exceeds 14.5 hours and develops them when it exceeds 13.5 hours. It is traditionally considered an autumn-flowering plant. However, by extending short days with supplementary lighting or shortening long days with shading/blackout methods, plants can be maintained in either vegetative or generative state, thereby delaying or advancing their flowering period. The day length and temperature from the end of March to August inhibit growth as well as the flower initiation process. Hence, provision to provide artificial short days during these months may result in flower initiation and development if the temperature is maintained at optimum levels. A key study from Dr. Y.S. Parmar University of Horticulture and Forestry, Solan (Himachal Pradesh) evaluated blackout materials like black satin cloth, high-density polyethylene (HDPE) and tarpaulin, reported that HDPE is the most effective for controlling the photoperiod to achieve off-season blooms.

Pinching is one of the most suitable practices for the successful cultivation of cut flowers as well as potted plants. Pinching is the removal of the terminal growing portion of the stem, which removes the source of apical dominance, and the assimilates are then diverted into lateral buds and hence branching occurs (). In most cases, pinching helps in delaying the onset of flowering. This is because the plant's energy is redirected from vertical growth and early flowering to the development of new branches. Therefore, pinching can be helpful in regulating the flowering time and quality of flower production.

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DOI: https://doi.org/10.21276/AATCCReview.2025.13.04.760

The interplay between short-day photoperiod and pinching in chrysanthemum cultivation has been comparatively understudied. Nevertheless, both factors are crucial for off-season greenhouse production and form the basis for production scheduling. However, very little work has been done in photoperiodic manipulation for flower regulation in chrysanthemum under the Tarai region of Uttarakhand. Therefore, to optimize the off-season flower production in spray type chrysanthemum cv Bidhan Shweta with different levels of pinching at different photoperiodic conditions, the present investigation was carried out during 2023-24 and 2024-25.

Materials and Methods

The present investigation was conducted at Model Floriculture Centre, G. B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand), during the cropping period from February to October of chrysanthemum for two years. The climate of the experimental site, Pantnagar, is humid subtropical with higher temperatures ranging from 32 to 43^{0}C during the summer season. The summers are hot and dry, with heavy rainfall during the rainy season. Pantnagar is located in the *Tarai* region of Uttarakhand, where its soil is classified under mollisols. The experimental material used for the research was a spray-type chrysanthemum variety named Bidhan Shweta. The plants of the chrysanthemum variety Bidhan Shweta were raised through the suckers at February end. The suckers were planted in the pots of 6-inch (15 cm) diameter containing a mixture of garden soil, well-rotted farmyard manure and vermicompost (2:1:1). The experiment was laid out in a Completely Randomized Design with 9 treatments and three replications consisting of five pots each. The treatments included: T_1: Natural photoperiod + no pinch (Control), T_2: Natural photoperiod + single pinch, T_3: Natural photoperiod + double pinch, T_4: Artificial short days began from April onwards + no pinch, T_5: Artificial short days began from April onwards + single pinch, T_6: Artificial short days began from April onwards + double pinch, T_7: Artificial short days began from June onwards + no pinch, T_8: Artificial short days began from June onwards + single pinch, T_9: Artificial short days began from June onwards + double pinch. The plants were given controlled photoperiodic treatments by subjecting them to artificial short days beginning when the plants had attained sufficient vegetative growth and the side branches had grown to one foot height after pinching. The pots were placed under artificially created short day conditions from April and June to the stage when 50- 60% flower buds show colour. To provide artificial short days, an inverted "U" shaped bamboo tunnel (3 m × 1.5 m × 1.5 m) completely covered with 100-micron HDPE was placed over the pots for 15 hours regularly from 5 pm to 8 am every day. The plants were maintained under artificial short days till 60-70% of the flower buds showed colour and were subsequently shifted to natural daylight conditions. The plants were subjected to three levels of pinching: no pinching, a single pinch at two weeks after planting and a double pinch performed at two and four weeks after planting. Recommended cultural practices were followed to raise the plants for optimum growth and flowering.

Results and Discussion

The observations on various vegetative and flowering attributes recorded and analyzed statistically during the experimentation period 2023-24 and 2024-25 are presented below:

Vegetative Parameters

The data recorded on the effect of pinching on various vegetative parameters in cv. Bidhan Shweta grew as a pot mum in a 6-inch pot at different photoperiodic conditions during 2023-24 and 2024-25, along with pooled analysis, are presented in Table 1. The observations, such as plant height (cm), plant spread (cm) and number of branches per plant, were recorded at the peak flowering stage.

Plant height (cm)

During 2023-24, the highest plant height (49.69 cm) was observed in T_1 (control), followed by T_2 (Natural photoperiod + single pinch) with a plant height of 47.53 cm. The minimum plant height (32.66 cm) was recorded in T_6 (Artificial short days beginning from April onwards + double pinch). In the year 2024-25, the highest plant height (43.93 cm) was again observed in T_1 (control), while the minimum plant height (29.18 cm) was observed in T_6 (Artificial short days beginning from April onwards + double pinch). The pooled data of both years indicated that the highest plant height (46.81 cm) was observed in the treatment T_1 (control), and the lowest plant height (30.92 cm) was found in T_6 (Artificial short days beginning from April onwards + double pinch). The untreated control group T_1 consistently had the tallest plants, since plants received a greater number of long days as compared to other groups. This makes sense because exposure to longer days leads to more vegetative growth. This is why the plant height was greater when exposed to short day conditions starting from June compared to those which were exposed to short days conditions that began in April. These results align with the findings of (4; 5 6). Additionally, the study also suggested an inverse relationship between pinching frequency and plant height in chrysanthemum cv. 'Bidhan Shweta'. This is because removing the apical portion of the main stem eliminates apical dominance and results in a bushier plant with more lateral branches and spread of plants, thus, eventually reducing the overall height of the plant. Similar trends of reduced plant height and increased branching due to pinching have been reported by (7) in annual chrysanthemum and (8) in *Chrysanthemum indicum*.

Plant spread (cm)

During the year 2023-24, highest plant spread (32.31 cm) was recorded in T_3 (Natural photoperiod + double pinch) followed by T_9 (Artificial short days beginning from June onwards + double pinch) with plant spread of 31.61 cm and minimum plant spread (21.94 cm) was noted in T_4 (Artificial short days beginning from April onwards + no pinch). In the year 2024-25, the maximum plant spread (35.57 cm) was found in T_3 (Natural photoperiod + double pinch), followed by T_2 (Natural photoperiod + single pinch) with a plant spread of 34.68 cm and the minimum plant spread (23.44 cm) was noted in T_4 (Artificial short days beginning from April onwards + no pinch). The pooled data of both years indicate that the highest plant spread (33.94 cm) was observed in the treatment T_3 (Natural photoperiod + double pinch), and the lowest plant spread (22.69 cm) was found in T_4 (Artificial short days beginning from April onwards + no pinch). The increase in plant spread is influenced by both environmental and mechanical factors. Plants grown under natural photoperiod grow significantly broader than those in controlled conditions since they are exposed to longer days. These results are corroboration by the findings of (9; 6). Additionally, the frequency of pinching directly encourages the production of side shoots, and the plant becomes bushy (10).

Number of side shoots per plant

During 2023-24, highest number of side shoots per plant (7.52) were recorded in T_3 (Natural photoperiod + double pinch) which was significantly at par with T_9 (Artificial short days beginning from June onwards + double pinch) with 7.44 branches and the minimum of number of side shoots (2.91) were recorded in T_4 (Artificial short days beginning from April onwards + no pinch). Whereas, in the year 2024-25, the maximum number of side shoots (7.78) were observed in T3 (Natural photoperiod + double pinch) followed by T_9 (Artificial short days beginning from June onwards + double pinch) with 7.69 side shoots and the minimum number of side shoots (2.29) were observed in T_4 (Artificial short days beginning from April onwards + no pinch). As per the pooled analysis of both years, the maximum number of side shoots (7.65) was observed in T_3 (Natural photoperiod + double pinch), whereas, minimum number of side shoots (2.60) was recorded in T_4 (Artificial short days beginning from April onwards + no pinch). Pinching stimulates cell division and photosynthetic compound production, which eventually encourages the number of side shoots (11; 12). The maximum number of branches observed in natural conditions is attributed to a prolonged vegetative growth phase, which is induced by long-day photoperiods, as well as by the quality of natural light and ambient temperatures (13).

Table 1: Effect of pinching on plant height, plant spread and number of side shoots/plant at different photoperiodic conditions in chrysanthemum cv. Bidhan Shweta

Treatment	Plant height (cm)			Plant spread (cm)			No. of side shoots/plant		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1 (Control)	49.69^{a}	43.93^{a}	46.81^{a}	28.36^{b}	31.98^{b}	30.17^{b}	3.18^{e}	3.23^{d}	3.20^{e}
T_2	47.53^{b}	41.89^{b}	44.71^{b}	29.54^{b}	34.68^{a}	32.11^{a}	4.71^{c}	4.68^{b}	4.70^{c}
T_3	43.92^{c}	39.87^{c}	41.90^{c}	32.31^{a}	35.57^{a}	33.94^{a}	7.52^{a}	7.78^{a}	7.65^{a}
T_4	37.29^{e}	31.43^{d}	34.36^{ef}	21.94^{d}	23.44^{d}	22.69^{d}	2.91^{e}	2.29^{e}	2.60^{f}
T_5	34.56^{f}	30.39^{de}	32.48^{g}	25.51^{c}	27.77^{c}	26.64^{c}	4.18^{d}	3.84^{c}	4.01^{d}
T_6	32.66^{g}	29.18^{e}	30.92^{h}	31.20^{a}	34.43^{a}	32.82^{a}	6.75^{b}	7.41^{a}	7.08^{b}
T_7	40.77^{d}	32.20^{d}	36.48^{d}	22.85^{d}	25.62^{cd}	24.24^{d}	3.04^{e}	2.75^{de}	2.89^{ef}
T_8	38.37^{e}	31.89^{d}	35.13^{e}	26.26^{c}	27.88^{c}	27.07^{c}	4.47^{cd}	4.39^{b}	4.43^{cd}
T_9	36.86^{e}	30.06^{de}	33.46^{fg}	31.61^{a}	34.45^{a}	33.03^{a}	7.44^{a}	7.69^{a}	7.56^{ab}
C.D. (p = 0.05)	**2.52**	**3.82**	**1.68**	**2.55**	**5.48**	**3.03**	**0.25**	**0.29**	**0.24**
SE (m) ±	**0.84**	**1.27**	**0.56**	**0.85**	**1.83**	**1.01**	**0.08**	**0.10**	**0.08**

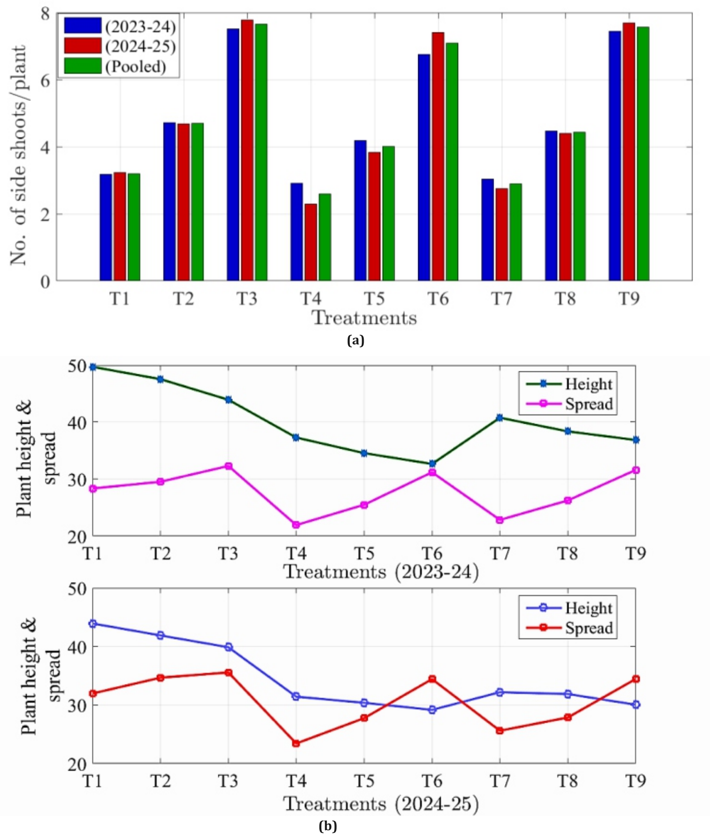

Fig 1: Graph showing the influence of pinching at different photoperiodic conditions on vegetative parameters in chrysanthemum cv. Bidhan Shweta (a) number of side shoots per plant (b) plant height and spread

Flowering parameters

The data related to effect of different pinching levels at different photoperiodic conditions on various flowering parameters like flower diameter and number of flowers per plant were recorded at the peak flowering stage, while, days taken to flower bud initiation, days taken to flower bud opening, days taken to 50% flowering and days taken to 100% flowering were recorded from date of planting of rooted cuttings in the 6-inch pot and are presented in tabulated form in Table 2.

Days taken to flower bud initiation

Days taken to flower bud initiation in plants is an important attribute as it depicts earliness or delay in flowering among different treatments. In the first year, 2023-24, the minimum number of days taken to flower bud initiation (75.71 days) was observed in treatment T_4 (Artificial short days beginning from April onwards + no pinch) among different treatments, followed by treatment T_5 (Artificial short days beginning from April onwards + single pinch) (87.57 days). The treatment T_3 (Natural photoperiod + double pinch) took the maximum days for initiation of flower buds (192.26 days), which was statistically higher than the other treatments. In the second year, 2024-25, the minimum number of days taken to flower bud initiation (73.42 days) was observed in treatment T_4 (Artificial short days beginning from April onwards + no pinch) among different treatments. The next best treatment to initiate early flowering (85.78 days) was observed in treatment T_5 (Artificial short days beginning from April onwards + single pinch). The treatment T_3 (Natural photoperiod + double pinch) took the maximum days for initiation of flower buds (193.37 days), which was immediately followed by T_2 (Natural photoperiod + single pinch) and T_1 (Natural photoperiod + no pinch) with 182.33, 177.17 days, respectively. As per the pooled data of both years, the minimum number of days taken for flower bud initiation (74.56 days) was in treatment T_4 (Artificial short days beginning from April onwards + no pinch) which was followed by T_5 (Artificial short days beginning from April onwards + single pinch) (86.67 days) and T_6 (Artificial short days beginning from April onwards + double pinch) (102.26 days). However, treatment T_3 (Natural photoperiod + double pinch) took the maximum days for initiation of flower buds (192.82 days). In case of controlled photoperiodic conditions, plants were given artificial short-day conditions, which advanced floral initiation relative to natural photoperiod. This response is likely due to precise photoperiodic manipulation that accelerates the shift from vegetative to reproductive growth.

These results are in close agreement with the findings of (14; 13) An increase in the number of pinching resulted in a significant delay in flower bud formation. This delay occurred because pinching removed the physiologically mature portion, and new shoots that emerged after pinching took more time to become physiologically inductive to produce flower buds. These findings are consistent with the observations reported by (15; 8)

Days taken to flower bud opening

The statistical analysis of data shows that all the treatments exhibited a significant impact on the days taken for flower bud opening in chrysanthemum cv. Bidhan Shweta, when compared to the untreated control group. In the first year 2023-24, among different treatments, the minimum number of days taken to flower bud opening (87.43 days) was observed in treatment T_4 (Artificial short days beginning from April onwards + no pinch). Another promising treatment combination for early flower bud opening was seen in treatment T_5 (Artificial short days beginning from April onwards + single pinch) (99.58 days). The treatment T_3 (Natural photoperiod + double pinch) took the maximum days to flower bud opening (204.44 days), which was followed by T_2 (Natural photoperiod + single pinch) (191.72 days) and T_1 (Natural photoperiod + no pinch) (187.39 days). In the second year 2024-25, the minimum number of days taken to flower bud opening (85.56 days) was observed in treatment T_4 (Artificial short days beginning from April onwards + no pinch) among different treatments and was found to be significantly lower than treatment T_5 (Artificial short days beginning from April onwards + single pinch) (97.48 days). The treatment T_3 (Natural photoperiod + double pinch) took the maximum days to flower bud opening (204.44 days), which was followed by T_2 (Natural photoperiod + single pinch) and T_1 (Natural photoperiod + no pinch) with 195.28 and 189.33 days, respectively. As per the pooled data of both years, the minimum number of days taken to flower bud opening (86.50 days) was in treatment T_4 (Artificial short days beginning from April onwards + no pinch) followed by T_5 (Artificial short days beginning from April onwards + single pinch) (98.53 days) and T_6 (Artificial short days beginning from April onwards + double pinch) (114.58 days). However, treatment T_3 (Natural photoperiod + double pinch) took the maximum days to flower bud opening (204.44 days). Earliest flower bud opening was recorded in treatment T_4 (artificial short days from April onward + no pinching), demonstrating a clear association between early floral initiation and subsequent advancement in flower opening under this regime. The integration of pinching with controlled photoperiod provides an effective approach for regulating both vegetative growth and flowering behaviour. While pinching inherently delays the onset of bud formation by removing physiologically mature tissues, the application of artificial short-day conditions can partially offset this delay by promoting earlier floral induction. The strong photoperiodic stimulus created by the short-day environment acts as a hormonal trigger, compelling even newly formed lateral shoots to transition to the reproductive phase earlier than they would under natural conditions. Similar interactions between pinching-induced delays and photoperiod-mediated floral promotion have been reported by (8; 16).

Days taken to 50% flowering

Upon analysis of the recorded observations, a significant reduction in days taken to 50% flowering was observed in the chrysanthemum variety Bidhan Shweta with the different pinching levels at different photoperiodic conditions. In the year 2023-24, among different treatments earliest 50% flowering (108.44 days) was observed in treatment T_4 (Artificial short days beginning from April onwards + no pinch) which was found statistically higher than other treatments like T_5 (Artificial short days beginning from April onwards + single pinch) (120.77 days) and T_6 (Artificial short days beginning from April onwards + double pinch) (138.43 days). The treatment T_3 (Natural photoperiod + double pinch) took maximum days to 50% flowering (224.50 days), which was followed by T_2 (Natural photoperiod + single pinch) (212.47 days) and T_1 (Natural photoperiod + no pinch) (207.40 days). In the second year, 2024-25, the minimum number of days taken to 50% flowering (105.44 days) was observed in treatment T_4 (Artificial short days beginning from April onwards + no pinch) among different treatments and was found to be significantly lower than treatment T_5 (Artificial short days beginning from April onwards + single pinch) (117.75 days). The treatment T_3 (Natural photoperiod + double pinch) took the maximum days to 50% flowering (225.48 days), which was followed by T_2 (Natural photoperiod + single pinch) and T_1 (Natural photoperiod + no pinch) with 215.43 and 210.61 days, respectively. As per the pooled data analysis, the minimum number of days taken to 50% flowering (106.94 days) was in treatment T_4 (Artificial short days beginning from April onwards + no pinch), which was significantly superior to all other treatment combinations. However, treatment T_5 (Artificial short days beginning from April onwards + single pinch) and T_6 (Artificial short days beginning from April onwards + double pinch) were also found earlier to initiate 50% flowering in 119.26 and 135.51 days, respectively. However, treatment T_3 (Natural photoperiod + double pinch) took the maximum days for 50% flowering (224.99 days). Controlled photoperiod resulted in early flowering, as flowering is not determined by the length of the day but by the length of the uninterrupted dark period, which is controlled by a group of photoreceptors called phytohormones. Whereas, in the case of natural photoperiod, chrysanthemum blooms in the fall because that is when days shorten and nights lengthen. These observations are consistent with the findings of (14; 13) who reported accelerated flowering under controlled short-day photoperiods in chrysanthemum. Likewise, the delaying influence of pinching observed in this study aligns with the results of (17; 18), who attributed delayed floral initiation to the removal of physiologically mature apical tissues and the subsequent vegetative regeneration of lateral shoots.

Days taken to 100% flowering

The statistical data analysis of the data shows that all the treatments with different pinching levels at different photoperiodic conditions exhibited a significant impact on the days taken to 100% flowering in chrysanthemum cv. Bidhan Shewta, when compared to the untreated control. In the year 2023-24, maximum advancement in days taken to 100% flowering (123.87 days) was observed in treatment T_4 (Artificial short days beginning from April onwards + no pinch) followed by treatment T_5 (Artificial short days beginning from April onwards + single pinch) and T_6 (Artificial short days beginning from April onwards + double pinch) with 135.70 and 153.43 days, respectively. The maximum number of days taken to 100% flowering (240.40 days) was recorded in treatment T_3 (Natural photoperiod + double pinch), which was significantly superior to other treatments like T_2 (Natural photoperiod + single pinch) (226.47 days) and T_1 (Natural photoperiod + no pinch) (222.51 days). In the year 2024-25, minimum number of days taken to 100% flowering (120.37 days) was observed in treatment T_4 (Artificial short days beginning from April onwards + no pinch) which was followed by treatment T_5 (Artificial short days beginning from April onwards + single pinch) and T_6 (Artificial short days beginning from April onwards + double pinch) with 132.51 and 147.70 days, respectively. Highest number of days taken to 100% flowering (240.75 days) was recorded in treatment T_3 (Natural photoperiod + double pinch). The other treatments, which took significantly longer days to 100% flowering, include T_2 (Natural photoperiod + single pinch) (230.47 days) and T_1 (Natural photoperiod + no pinch) (225.43 days). As per the pooled data analysis, the minimum number of days taken to 100% flowering (122.12 days) was in treatment T_4 (Artificial short days beginning from April onwards + no pinch) which was followed by T_5 (Artificial short days beginning from April onwards + single pinch) (134.11 days) and T_6 (Artificial short days beginning from April onwards + double pinch) (150.57 days). However, treatment T_3 (Natural photoperiod + double pinch) took the maximum days to 100% flowering (240.57 days). The earliness in flowering may be because the artificial dark period involves the production of a mobile flowering hormone called florigen, specifically locus T (FT) protein, which is synthesized in leaves and transported to the apical meristem, where it initiates the genetic program for flower bud formation (19). These results are similar to the observations of (4; 5; 6) who also reported earlier flowering in chrysanthemum under controlled short-day treatments. On the contrary, delay in flowering is attributed to the frequency of pinching as it prevents apical dominance caused by auxin (20) Similar delaying effects of pinching in chrysanthemum have been documented by (7; 8).

Number of flowers per plant

In the year 2023-24, T_3 (Natural photoperiod + double pinch) showed a significantly greater number of flowers per plant (62.96) than all other treatments, followed by T_9 (Artificial short days beginning from June onwards + double pinch) and T_6 (Artificial short days began from April onwards + double pinch) with 58.27 and 52.12, respectively. However, the minimum number of flowers per plant (23.58) was found in T_4 (Artificial short days beginning from April onwards + no pinch). In the year 2024-25, the maximum number of flowers per plant (65.87) was recorded in T_3 (Natural photoperiod + double pinch), which was followed by T_9 (Artificial short days beginning from June onwards + double pinch) and T6 (Artificial short days beginning from April onwards + double pinch) with 55.68 and 53.12, respectively. The minimum number of flowers per plant (20.56) was spotted in T_4 (Artificial short days beginning from April onwards + no pinch). As per the pooled data analysis of both years, treatment T_3 (Natural photoperiod + double pinch) exhibited the highest number of flowers per plant (64.41), followed by T_9 (Artificial short days beginning from June onwards + double pinch) and T_6 (Artificial short days beginning from April onwards + double pinch) with 56.97 and 52.62, respectively. The minimum number of flowers per plant (22.07) was observed in T_4 (Artificial short days beginning from April onwards + no pinch). The number of flowers per plant increased with pinching, primarily due to the enhanced production of lateral shoots that subsequently contributed to a greater number of floral stems. This trend is consistent with the findings of (21) in marigold, (22) in China aster, and (23) in annual chrysanthemum. A similar finding was reported by (14), who reported, maximum number of flowers per plant under natural photoperiod conditions as compared to controlled photoperiod.

Flower diameter (cm)

On thorough examination, significant differences were observed in all the treatments consisting of different pinching levels at different photoperiodic conditions. In the year 2023-24, among treatments maximum diameter of the flower (6.95 cm) was observed in treatment T_3 (Natural photoperiod + double pinch). On the contrary, minimum diameter of flower (4.23 cm) was found in treatment T_4 (Artificial short days beginning from April onwards + no pinch) which was followed by treatment T_5 (Artificial short days beginning from April onwards + single pinch) (4.56 cm) and T_6 (Artificial short days beginning from April onwards + double pinch) (4.95 cm). In the second year (2024-25), a similar trend was observed with the maximum diameter of the flower (6.57 cm) observed in treatment T_3 (Natural photoperiod + Double pinch) which was found to be statistically at par with T_2 (Natural photoperiod + Single pinch) (6.49 cm). Whereas, the minimum diameter of the flower (4.42 cm) was found in treatment T_4 (Artificial short days beginning from April onwards + no pinch), followed by treatment T_5 (Artificial short days beginning from April onwards + Single pinch) (4.75 cm) and T_6 (Artificial short days beginning from April onwards + double pinch) (5.25 cm). As per the pooled data of both years, the highest flower diameter (6.76 cm) was reported in T_3 (Natural photoperiod + double pinch), followed by T_2 (Natural photoperiod + single pinch) and T_1 (Natural photoperiod + no pinch) with flower diameters of 6.53 and 6.30 cm, respectively. However, the minimum flower diameter (4.32 cm) was observed in treatment T_4 (Artificial short days beginning from April onwards + no pinch). The reason for the increase in flower diameter with double pinching is mainly due to the reallocation of the plant's resources and the manipulation of hormonal balance. Unpinched plants dedicate all their resources to a single main stem. In contrast, a double pinched plant redirects the plant's energy and nutrients away from vertical growth and towards producing a robust, branched structure that can support larger and higher quality blooms. Similar physiological responses have been documented by (24) in cineraria, (25) in chrysanthemum, and (20) in marigold, who reported enlarged flower size under pinching treatments. The above results reinforce the reliability of natural photoperiod in enhancing flower size due to more favourable environmental conditions under natural photoperiod than controlled photoperiod. Similar observations were previously documented by (4; 5; 6) in chrysanthemum, supporting the role of natural photoperiod in maximizing flower size.

Table 2: Effect of pinching on days taken to first flower bud initiation, days to fully opened flower from bud opening and days to 50% flowering at different photoperiodic conditions in chrysanthemum cv. Bidhan Shweta

Treatment	Days taken to flower bud initiation			Days taken to flower bud opening			Days taken to 50% flowering		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1 (Control)	176.38^{c}	177.17^{c}	176.78^{c}	187.39^{c}	189.33^{c}	188.36^{c}	207.40^{c}	210.61^{c}	209.00^{c}
T_2	179.43^{b}	182.33^{b}	180.88^{b}	191.72^{b}	195.28^{b}	193.50^{b}	212.47^{b}	215.43^{b}	213.95^{b}
T_3	192.26^{a}	193.37^{a}	192.82^{a}	204.44^{a}	204.43^{a}	204.44^{a}	224.50^{a}	225.48^{a}	224.99^{a}
T_4	75.71^{i}	73.42^{i}	74.56^{i}	87.43^{i}	85.56^{i}	86.50^{i}	108.44^{i}	105.44^{i}	106.94^{i}
T_5	87.57^{h}	85.78^{h}	86.67^{h}	99.58^{h}	97.48^{h}	98.53^{h}	120.77^{h}	117.75^{h}	119.26^{h}
T_6	105.32^{g}	99.19^{g}	102.26^{g}	117.48^{g}	111.67^{g}	114.58^{g}	138.43^{g}	132.60^{g}	135.51^{g}
T_7	125.74^{f}	122.78^{f}	124.26^{f}	139.55^{f}	136.37^{f}	137.96^{f}	160.58^{f}	157.39^{f}	158.99^{f}
T_8	132.29^{e}	128.67^{e}	130.48^{e}	148.68^{e}	144.57^{e}	146.63^{e}	169.46^{e}	165.52^{e}	167.49^{e}
T_9	149.45^{d}	145.20^{d}	147.33^{d}	173.28^{d}	169.58^{d}	171.43^{d}	194.55^{d}	190.57^{d}	192.56^{d}
C.D. (p = 0.05)	**1.71**	**1.67**	**1.04**	**1.89**	**1.77**	**1.34**	**1.63**	**1.77**	**1.20**
SE (m) ±	**0.57**	**0.56**	**0.35**	**0.63**	**0.59**	**0.45**	**0.55**	**0.59**	**0.40**

Table 2 (Cont.): Effect of pinching on days to 100% flowering, no. of flowers per plant and flower diameter at different photoperiodic conditions in chrysanthemum cv. Bidhan Shweta

Treat-ment	Days taken to 100% flowering			No. of flowers per plant			Flower diameter (cm)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1 (Control)	222.51^{c}	225.43^{c}	223.97^{c}	32.78^{g}	27.56^{g}	30.17^{g}	6.28^{b}	6.32^{ab}	6.30^{ab}
T_2	226.47^{b}	230.47^{b}	228.47^{b}	44.13^{d}	50.23^{d}	47.18^{d}	6.57^{ab}	6.49^{a}	6.53^{a}
T_3	240.40^{a}	240.75^{a}	240.57^{a}	62.96^{a}	65.87^{a}	64.41^{a}	6.95^{a}	6.57^{a}	6.76^{a}
T_4	123.87^{i}	120.37^{i}	122.12^{i}	23.58^{i}	20.56^{i}	22.07^{i}	4.23^{e}	4.42^{d}	4.32^{d}
T_5	135.70^{h}	132.51^{h}	134.11^{h}	36.74^{f}	45.56^{f}	41.15^{f}	4.56^{de}	4.75^{d}	4.66^{d}
T_6	153.43^{g}	147.70^{g}	150.57^{g}	52.12^{c}	53.12^{c}	52.62^{c}	4.95^{d}	5.25^{c}	5.10^{c}
T_7	175.61^{f}	172.54^{f}	174.07^{f}	26.12^{h}	23.79^{h}	24.95^{h}	4.93^{d}	5.23^{c}	5.08^{c}
T_8	184.60^{e}	180.38^{e}	182.49^{e}	40.56^{e}	48.56^{e}	44.56^{e}	5.03^{d}	5.45^{c}	5.24^{c}
T_9	209.55^{d}	205.57^{d}	207.56^{d}	58.27^{b}	55.68^{b}	56.97^{b}	5.68^{c}	5.99^{b}	5.84^{b}
C.D. (p = 0.05)	**1.74**	**1.83**	**1.11**	**1.82**	**2.32**	**1.33**	**0.23**	**0.22**	**0.18**
SE (m) ±	**0.58**	**0.61**	**0.37**	**0.61**	**0.78**	**0.45**	**0.08**	**0.07**	**0.06**

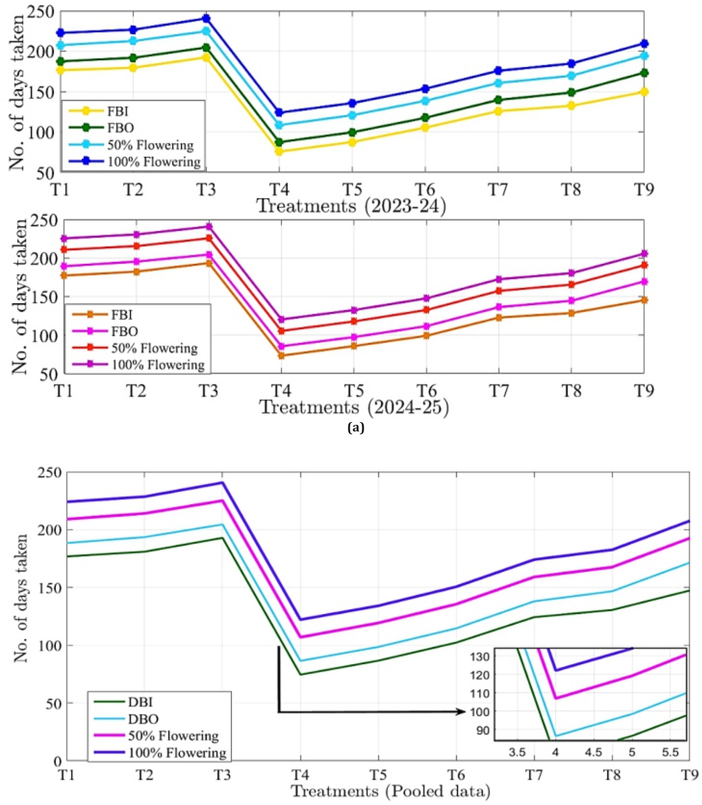

Fig 2: (a&b) Influence of pinching at different photoperiodic conditions on flowering in chrysanthemum cv. Bidhan Shweta: number of days to flower bud initiation (FBI), number of days to flower bud opening (FBO), number of days to 50% flowering and number of days to 100% flowering during the two consecutive years 2023-24 and 2024-25 and their pool data

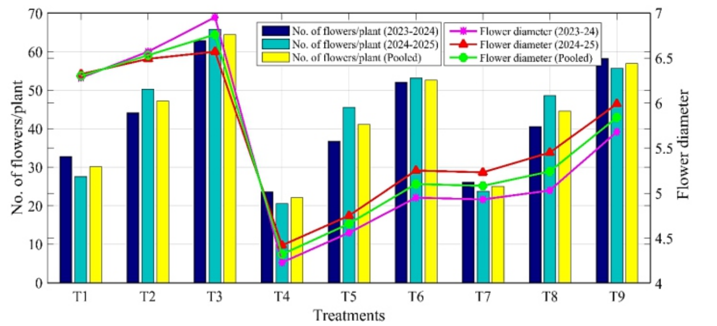

Fig 3: Influence of pinching at different photoperiodic conditions on flower yield in chrysanthemum cv. Bidhan Shweta: number of flowers per plant and flower diameter (cm) during the two consecutive year 2023-2024 and 2024-2025 and their pool data

Principal Component Analysis

The principal component analysis of all assessed parameters marked that the first two principal components (PCs) had eigenvalues greater than 1 and jointly summarized 99.5% of the total variance, accounting for 87.5% and 12.0% for PC1 and PC2, respectively. The Principal Component Analysis biplot (PC1 = 87.5%, PC2 = 12%) effectively differentiates the considerable sources of phenotypic variation among the nine treatments, mainly a range from earliness to aesthetic quality attributes. Treatments located on the negative side of PC1 (like T_4 artificial short days + no pinch) showed early flowering but with low quality for floral attributes, while those located on the positive side of PC1 (like T_3, T_9, T_2: natural photoperiod + pinching) exhibited delayed flowering but with enhanced flower diameter, number of branches and flower count. The secondary component (PC2), responsible for minor variations, primarily separating treatments based on the number of flowers, indicated that this treatment varied independently of phenological timing.

The spatial distribution of the data illustrates a clear trade-off between two production goals: either producing earlier off-season flowering to maximize market profitability, albeit with reduced aesthetic quality, or attaining delayed flowering during the main season correlated with superior aesthetic attributes. Collectively, the PCA suggests that statistical validation growers must strategically select in accordance with production goals either prioritizing off-season marketability or optimizing quality for peak season display.

Correlation Matrix Analysis

The correlation matrix (Figure 5) further validates the critical trade-off pattern revealed by PCA, quantitatively showing the correlation among the vegetative and floral time parameters. It reveals a strong positive correlation ($r \approx 1.00$) among all flowering time parameters like time taken for bud initiation, bud opening, 50% and 100% flowering elucidating their concurrent response to photoperiodic and pinching treatments. Conversely, these earliness traits show a strong negative correlation with vegetative growth parameters such as plant height ($r = -0.17$ to 0.29) and a moderate-to-weak correlation with quality parameters like flower diameter ($r = 0.46–0.55$) and yield per plant ($r = 0.46–0.49$).

In contrast, the cluster of aesthetic quality traits, plant spread, number of branches, and yield per plant show strong positive correlations with each other (0.85-0.95). Highlighting their collective effort to canopy structure and ornamental appeal. The negative relation between earliness and quality traits implies that treatments like early flowering (e.g., T_4) promote rapid phenological advancement but hinder the assimilate partitioning to vegetative and floral development. Conversely, treatments like that promote branching and spread (e.g., T3), improve floral yield and aesthetic quality, but lengthen the flowering period. These outcomes proved that it is not coincidental; there is a statistical relationship between the physiological and morphological trade-offs observed across treatments, validating the PCA interpretation and reinforcing the need for strategic treatment optimization according to production goals.

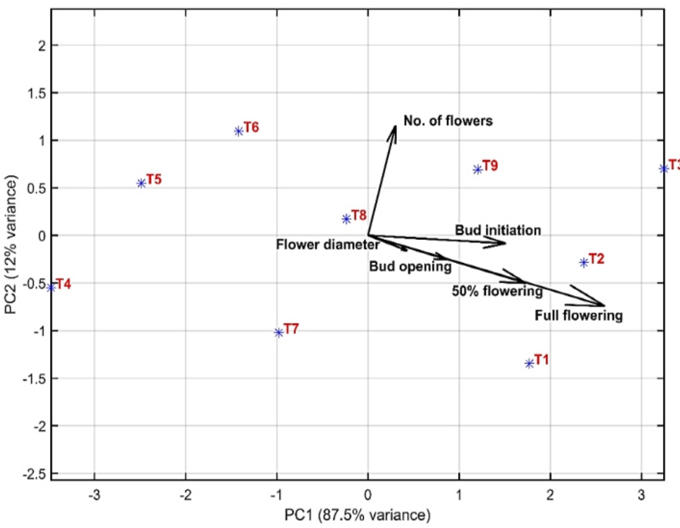

Fig 4: Principal component loading plot and scores of flowering time and floral quality attributes assessed under varied photoperiodic and pinching treatments in chrysanthemum. PC1 (87.5%) and PC2 (12.0%) represent the primary and secondary sources of variation, respectively. Treatments positioned on the negative side of PC1 correspond to early flowering responses under artificial short days, while those on the positive side indicate delayed flowering with enhanced flower diameter and floral yield under natural photoperiod with pinching. The plot clearly illustrates the trade-off between earliness and aesthetic attributes in response to different treatment combinations

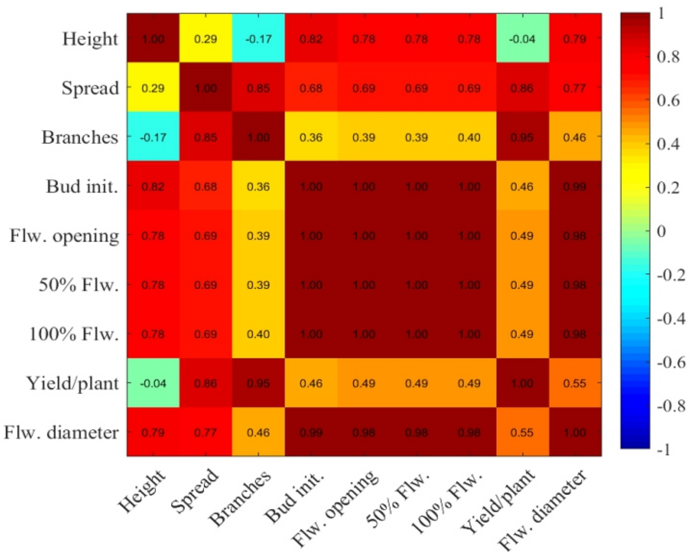

Fig 5: Correlation heat map illustrating pairwise relationships between vegetative and floral attributes in chrysanthemum cv. Bidhan Shweta under different photoperiodic and pinching treatments. The colour scale depicts the strength and direction of correlation (–1 to +1). Strong positive correlations were noticed among flowering stages and vegetative growth traits, while weak or negative relations were noted between earliness and quality parameters, validating the trade-off pattern identified in PCA

Conclusion

Based on the two years of research, it can be concluded that among different treatments, the best treatment for flower regulation depends on the grower's strategy to meet market goals, whether a trade-off between earliness and plant productivity. The treatment T_3 (Artificial short days from April + no pinch) was found to be most effective for inducing early off-season flowering during summer months, and helps in fetching a higher market price. It recorded the earliest flower bud initiation (74.56 days) and 100% flowering (122.12 days). The early flowering in T_3 (Artificial short days from April + no pinch) is because of a hormonal trigger, which is induced by exposing the plants to artificial short days. It results in the production of a mobile flowering hormone "florigen," which forces the plant to change from the vegetative to the reproductive phase much earlier than it might under natural conditions. Eventually, early flowering prevents the prolonged vegetative growth, resulting in smaller plants, a minimum number of branches (2.60), a number of flowers per plant (22.07) and the smallest flower size (4.32 cm). Whereas, T_2 (Natural photoperiod + double pinch) proved to be the best treatment in producing high-quality pot plants with maximum plant spread (33.94 cm), number of branches (7.65), number of flowers (64.41) and the largest flower size (6.76 cm). There are two reasons behind the produced superior quality pot plant of treatment T_2 (Natural photoperiod + double pinch): firstly, double pinching that prevents apical dominance, resulting in a bushier plants with more branches, flowers and bigger flower size and secondly, the natural long day photoperiod while the initial growth phase which promotes more vegetative growth, thereby aiding the plant to reserve ample amount of resources before the commencement of natural short days that induce flowering in autumn. However, this combination prominently delays flowering, taking the maximum time to initiate buds (192.82 days) and achieve 100% flowering (240.57 days). The former treatment has economic benefits, while the latter one is more appealing aesthetically.

Future Scope

The future of chrysanthemum farming should focus mainly on developing a protocol that successfully integrates early flowering induced by artificial short days with the superior plant architecture obtained via pinching. This could be achieved by exposing plants to artificial short days either at a stage when plants have attained sufficient vegetative growth or for a short duration to allow for more vegetative growth before flower induction. Additionally, plant growth regulators like cytokinin could be used along with pinching and photoperiod treatments to stimulate bushy growth and high flower count, even in early flowering and non-pinched groups. Studies should focus on how the early transport of florigen to the apical meristem might negatively regulate the genes responsible for lateral bud outgrowth. Recognizing and modulating these molecular signals could result in a cultivar that is both early flowering and structurally superior. Ultimately, this integrated approach will lead to a highly profitable production system where growers no longer have to compromise, achieving both fast, off-season harvests and high-quality, aesthetically appealing plants.

Acknowledgement

The author is thankful to ICAR - All India Coordinated Research Project (AICRP) on Floriculture for providing financial assistance and G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India, for providing the essential facilities, resources, and institutional support that enabled the successful completion of this research work.

Conflict of Interest

The authors declare there is no conflict.

References

1. Anderson, R. L. (1987). Reclassification of genus *Chrysanthemum*. *Journal of Horticultural Science*, 22(2), 313.

2. Vander Ploeg, A., and Heuvelink, E. (2006). The influence of temperature on growth and development of chrysanthemum cultivars: A review. *Journal of Horticultural Science and Biotechnology*, 81(2), 74-82.

3. Cline, M. G. (1991). Apical dominance. *Botanical Review*, 57, 318-358.

4. Usha. (2010). *Screening of newly evolved selection of chrysanthemum (Dendranthema grandiflora Tzvelev) for off-season flower production* (M.Sc. thesis). Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-Solan, H.P., 69 p.

5. Sultanpuri, A. (2013). *Effect of number of plants per pot, pot spacing and photoperiod on production of potted chrysanthemum (Dendranthema grandiflora Tzvelev)* (M.Sc. thesis). Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-Solan, H.P., 89 p.

6. Abrol, A. (2016). Effect of growth regulators on potted chrysanthemum (*Dendranthema grandiflora* Tzvelev) under different photoperiodic conditions. M.Sc. Thesis. Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-Solan, H.P.

7. Hawa, R. A., Gonane, S. U., and Panchbhai, D. M. (2021). Effect of planting time and pinching on growth of annual chrysanthemum. Journal of Pharmacognosy and Phytochemistry 10(2):104-109.

8. Ehsanullah, M., Tarapder, S. A., Maukeeb, A. R. M., and Khan, A. U. (2021). Effect of pinching on growth and quality flower production of chrysanthemum (*Chrysanthemum indicum* L.). *Journal of Multidisciplinary Applied Natural Science*, 1, 62-68.

9. Sita Ram. 1991. Studies on year round flower production in chrysanthemum (MSc Thesis). Dr. YS Parmar University of Horticulture and Forestry, Nauru, Solan (H.P.).

10. Awasthi, P., Joshi, D., and Rizal, G. (2022). Impact of pinching on growth and yield of marigold (*Tagetes erecta* L.). *Environment and Ecology Research*, 6, 34-38.

11. Amiri, M. A., Prakash, S., Singh, B., and Alam, K. (2021). The effect of pinching on growth and yield of chrysanthemum (*Chrysanthemum morifolium* cv. Snowball). *Progressive Agriculture*, 21(2), 235-238.

12. Chundawat, A. S., Jodha, A. S., Visen, D., Pareek, V., Jaiswani, S., Singh, S., Singh, C., and Champawat, T. S. (2025). Effect of pinching and cycocel on growth and yield of African marigold (*Tagetes erecta* L.). *Journal of Agricultural Science*, 21(1), 52-57.

13. Phairohlui, R., Keditsu, R., and Game, M. (2023). Effect of shading materials on the performance of spray chrysanthemum (*Chrysanthemum morifolium* Ramat.). *Journal of Pharmacology and Innovation*, 12(6), 646-650.

14. Dhiman, S. R., Gupta, Y. C., Thakur, P., Kashyap, B., and Sharma, M. (2017). Response of different chrysanthemum cultivars under natural and controlled photoperiodic conditions for pot mum production. *Journal of Hill Agriculture*, 8(3), 283-287.

15. Rajan, K., Bhatt, D. S., Chawla, S. L., Bhatt, S. T., and Sangeetha, P. S. (2019). Effect of nitrogen and phosphorus on growth, flowering and yield of cut chrysanthemum cv. Thai Chen Queen. *Current Agriculture Research Journal*, 7, 337-342.

16. Datta, S. K., and Gupta, V. N. (2012). Year round cultivation of garden Chrysanthemum (*Chrysanthemum morifolium* Ramat.) through photoperiodic response. 71-77.

17. Nagdeve, N. S., Khobragade, H. M., Thakare, A. A., Gajbhiye, R. P., and Mandhare, K. S. (2021). Effect of plant spacing and pinching on growth and flower yield of annual chrysanthemum. *International Journal of Chemical Studies*, 9(1), 491-495.

18. Jureshiya, Y., Sahu, T. L., and Sushila. (2021). Effect of pinching on flowering and quality parameters of chrysanthemum varieties. *Journal of Pharmacology and Innovation*, 10(10), 1579-1581.

19. Garner, W. W., and Allard, H. A. (1920). Effect of relative length of day and night and other factors of the environment on growth and reproduction in plants. *Journal of Agricultural Research*, 18, 553-606.

20. Sedhai, R., Katel, S., and Adhikari, A. (2024). Effect of pinching on growth, flowering, and yield of African marigold (*Tagetes erecta* L.) cv. Calcutta Local. *Fundamental and Applied Agriculture*, 9(3), 204-212.

21. Malshe, K. V., Salvi, B. R., and Sagvekar, V. V. (2021). Flowering and yield in marigold (*Tagetes* spp.) cv. Pusa Basanti Gainda as influenced by mulching and pinching practices. *Journal of Eco-Friendly Agriculture*, 16(2), 133-136.

22. Chopde, N., Palekar, A. R., and Satar, V. P. (2019). Growth, yield and quality of China aster varieties as influenced by pinching. *Journal of Pharmacognosy and Phytochemistry*, 8(2), 2150-2152.

23. Jena, S., and Mohanty, C. R. (2021). Effect of spacing on growth and flowering of annual chrysanthemum (*Chrysanthemum coronarium* L.). *Journal of Pharmacognosy and Phytochemistry*, 10(2), 1045-1050.

24. Abdou, M. A., Fouad, A. H., and Hassan, A. (2023). Influence of compost fertilization and pinching number on growth and flowering of *Cineraria* plant. *Journal of Agricultural Science*, 5(2), 17-30.

25. Sahu, J. K., Sahu, D., Kispotta, G. S., and Nag, K. (2024). Effects of pinching and plant growth regulators on chrysanthemum productivity in the central plain zone of Punjab. *Environment Conservation Journal*, 25(2), 575-580.

