



Influence of photoperiodic conditions on growth and flowering of chrysanthemum (*Dendranthema grandiflora* Tzvelev) genotypes for off-season flower production

Aman Guleria¹, Sita Ram Dhiman^{2*}, Meenakshi Basoli², Nitin Sharma³,
Rakesh Kumar Gupta³ and Gunjeet Kumar¹

¹Division of Floriculture and Landscaping, ICAR-IARI, New Delhi 110012, India

ABSTRACT

Chrysanthemum is a leading cut flower crop, but its strong photoperiodic sensitivity restricts year-round availability. Expanding production into the off-season requires identification of genotypes that combine adaptability with superior floral traits. In 2023, twenty-one genotypes were evaluated under natural and controlled photoperiodic conditions in a naturally ventilated polyhouse using a factorial Randomized Block Design with three replications. Photoperiod significantly influenced growth and flowering responses. Natural photoperiod promoted vegetative vigour and yield attributes, resulting in higher plant height (134.16 cm), greater spread (40.07 cm), increased stem number (6.83), stem length (81.28 cm), stem weight (35.06 g), flowers per stem (12.14), flower diameter (5.79 cm), flowering duration (29.85 days) and vase life (12.85 days). Controlled photoperiod accelerated reproductive transition, resulting in markedly earlier bud initiation (78.81 days) and flowering (136.07 days), while sustaining yields comparable to natural conditions. Substantial genotypic variability was observed, reflecting differential adaptation to photoperiod manipulation. These findings demonstrate that natural photoperiod enhances vegetative growth and floral quality, whereas controlled photoperiod enables precise crop scheduling with minimal yield penalties. Photoperiod regulation, therefore, represents an effective strategy for aligning chrysanthemum supply with market demand, offering new opportunities for off-season cultivation, resource use efficiency and breeding of genotypes with wider adaptability.

Key words: Crop scheduling, growth dynamics, floral quality, photoperiod.

INTRODUCTION

Chrysanthemum (*Dendranthema grandiflora* Tzvelev) is one of the most important commercially cultivated flowers, valued for cut, loose and pot mum production. Native to the Northern Hemisphere, particularly Europe and Asia, it is popularly known as the “Queen of the East” (Koley & Sarkar, 12), “Autumn Queen,” “Guldaudi” in India and “Mum” in the United States. Belonging to the family *Asteraceae*, chrysanthemum is globally recognized for its wide colour range, extended vase life and cultural significance.

In India, chrysanthemum is cultivated on about 45.14 thousand hectares, producing 1039.05 thousand tonnes annually, including 998.33 thousand tonnes of loose flowers and 40.72 thousand tonnes of cut flowers (Anonymous, 2). Andhra Pradesh leads production with 451.83 thousand tonnes, followed by Tamil Nadu and Andhra Pradesh. In Himachal Pradesh, 95.66 hectares are under chrysanthemum, with

73.86 hectares for loose flowers and 21.80 hectares for cut flowers (Anonymous, 3). Chrysanthemum is a qualitative short-day plant, highly sensitive to photoperiod, requiring long days for vegetative growth and short days for floral initiation. Flower bud initiation is inhibited when day length exceeds 14.5 hours, while vegetative growth is promoted under day lengths longer than 13.5 hours. Conversely, 12 hours or less is optimal for reproductive development. Photoperiodic responses can be regulated through environmental manipulations such as artificial lighting, blackout systems, optimized fertilization and growth regulators. These techniques enable successful year-round cultivation, enhancing the crop's commercial importance and market demand.

Despite the availability of off-season cultivars, there is a continuing need for novel genotypes with distinct flowering behavior, superior ornamental traits and wider adaptability. Aligning production with fluctuating market demand while avoiding oversupply during peak seasons is essential for profitability and sustainability in floriculture. In present investigation was conducted to evaluate newly developed chrysanthemum genotypes under off-

*Corresponding author email: sitaramdhiman@yahoo.co.in

²Department of Floriculture and Landscape Architecture, Dr YS Parmar UHF Nauni, Solan (H.P.)-173230, India

³Department of Basic Sciences, Dr YS Parmar UHF Nauni, Solan (H.P.)-173230, India

season conditions, with the objective of identifying promising types suitable for enhancing farmer income, crop diversification and year-round flower availability.

MATERIALS AND METHODS

The research was conducted in 2023 at the Research Farm of the Department of Floriculture and Landscape Architecture, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh). The experimental site, situated in a naturally ventilated polyhouse, lies at an altitude of 1276 m above mean sea level, at 30°51'0" N latitude and 77°11'30" E longitude. The region is characterized by a sub-temperate to subtropical climate. Meteorological data during the crop period are presented in Fig. 1. The experiment was laid out in a factorial Randomized Block Design (RBD) comprising 42 treatment combinations (2 photoperiodic conditions × 21 genotypes) with three replications. Treatments were randomly allocated to ensure statistical precision.

Genotypes (G): UHFSCChr-134/G1, UHFSCChr-135/G2, UHFSCChr-136/G3, UHFSCChr-137/G4, UHFSCChr-138/G5, UHFSCChr-140/G6, UHFSCChr-141/G7, UHFSCChr-142/G8, UHFSCChr-143/G9, UHFSCChr-145/G10, UHFSCChr-146/G11, UHFSCChr-147/G12, UHFSCChr-148/G13, UHFSCChr-149/G14, UHFSCChr-152/G15, UHFSCChr-153/G16, UHFSCChr-155/G17, UHFSCChr-156/G18, UHFSCChr-158/G19, UHFSCChr-159/G20, UHFSCChr-160/G21.

Rooted cuttings of 21 genotypes were prepared between 26 and 28 March from healthy, disease-free mother plants in early morning hours (5:00–8:00 a.m.). Cuttings (5–7 cm) were disinfected by dipping in Mancozeb (0.2%) and Carbendazim (0.1%) solution for 30 minutes, followed by removal of basal leaves and a sharp cut just below the node. The basal ends were treated with NAA (500 ppm) using a quick-dip method, before planting in pro-trays filled with cocopeat. Pro-trays were maintained in trenches

(45 cm deep, 60 cm wide) under portable poly-sheet tunnels to ensure high humidity. Trenches were drenched with Mancozeb (0.2%) and Carbendazim (0.1%) and irrigated before placement. Rooting occurred within 20 days and uniform rooted cuttings were transplanted on 23rd April at a spacing of 20 × 15 cm, accommodating seven plants per row on 1.5 m wide beds. All genotypes were maintained as spray-type chrysanthemums.

Controlled photoperiod was imposed by providing artificial short days from 3rd June to 15th September using portable metallic tunnels (3 × 1.5 × 1.65 m) covered with 200-micron HDPE sheets (Sangma *et al.*, 17). Covers were applied daily for 16 hours (5:00 p.m. to 9:00 a.m.) until 60–70% of flower buds on a plant showed colour, following earlier recommendations (Dhiman and Sehgal, 5; Abrol *et al.*, 1).

From each treatment and replication, five plants were randomly selected for observations. Data were recorded on vegetative traits: plant height (cm) and plant spread (cm). Flowering and quality traits: days to bud initiation, days to 50% flowering, number of cut stems per plant, length of cut stem (cm), weight of cut stem (g), flower diameter (cm), number of flowers per stem, flowering duration (days), and vase life (days). All measurements were taken at appropriate growth stages following standard horticultural protocols. Data were analyzed using RStudio (version 2025.05.0+496). Statistical analysis was carried out as per factorial RBD following the procedure described by Gomez and Gomez (10).

RESULTS AND DISCUSSION

Different photoperiodic conditions significantly influenced plant height, plant spread, days to bud initiation, days to flowering, number of cut stems per plant, stem length, stem weight, flower diameter, number of flowers per stem, flowering duration and vase life in *Chrysanthemum* genotypes. Significant variation among genotypes for these traits may be attributed to their distinct genetic makeup and differential responses to photoperiodic conditions.

Plant height was markedly greater under the natural photoperiod (134.16 cm) than under the controlled photoperiod (85.07 cm). Among the genotypes, 'UHFSCChr-135' recorded the maximum plant height (145.55 cm), whereas 'UHFSCChr-156' was the shortest (80.52 cm) (Fig. 2a). Similarly, plant spread was higher under the natural photoperiod (40.07 cm) compared with the controlled photoperiod (29.04 cm), with the maximum spread recorded in 'UHFSCChr-158' (44.80 cm) and the minimum in 'UHFSCChr-136' (22.83 cm) (Fig. 2b and Table 2). The greater vegetative growth under natural photoperiods

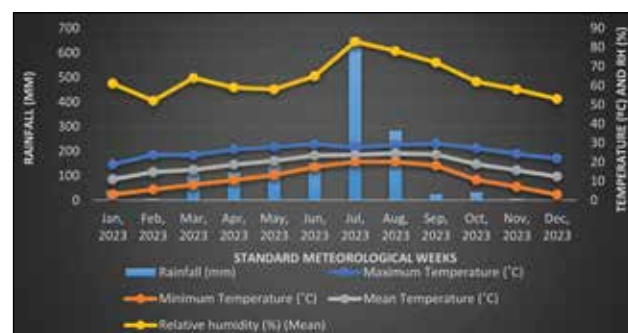


Fig. 1. Mean monthly meteorological data of research location.

may be associated with a prolonged vegetative phase, whereas short-day conditions promote an earlier transition from vegetative to reproductive development. Under short-day conditions, florigen, a systemic signal synthesized in leaves, is transported to the shoot apical meristem (Turck *et al.*, 20; Lee *et al.*, 13), where it promotes the transition of the shoot

apical meristem into an inflorescence meristem. In contrast, vegetative growth is maintained under long days and night-break treatments (Higuchi, 11). Thus, the earlier reproductive transition under controlled short-day conditions may have restricted vegetative growth, resulting in shorter plants and reduced plant spread.

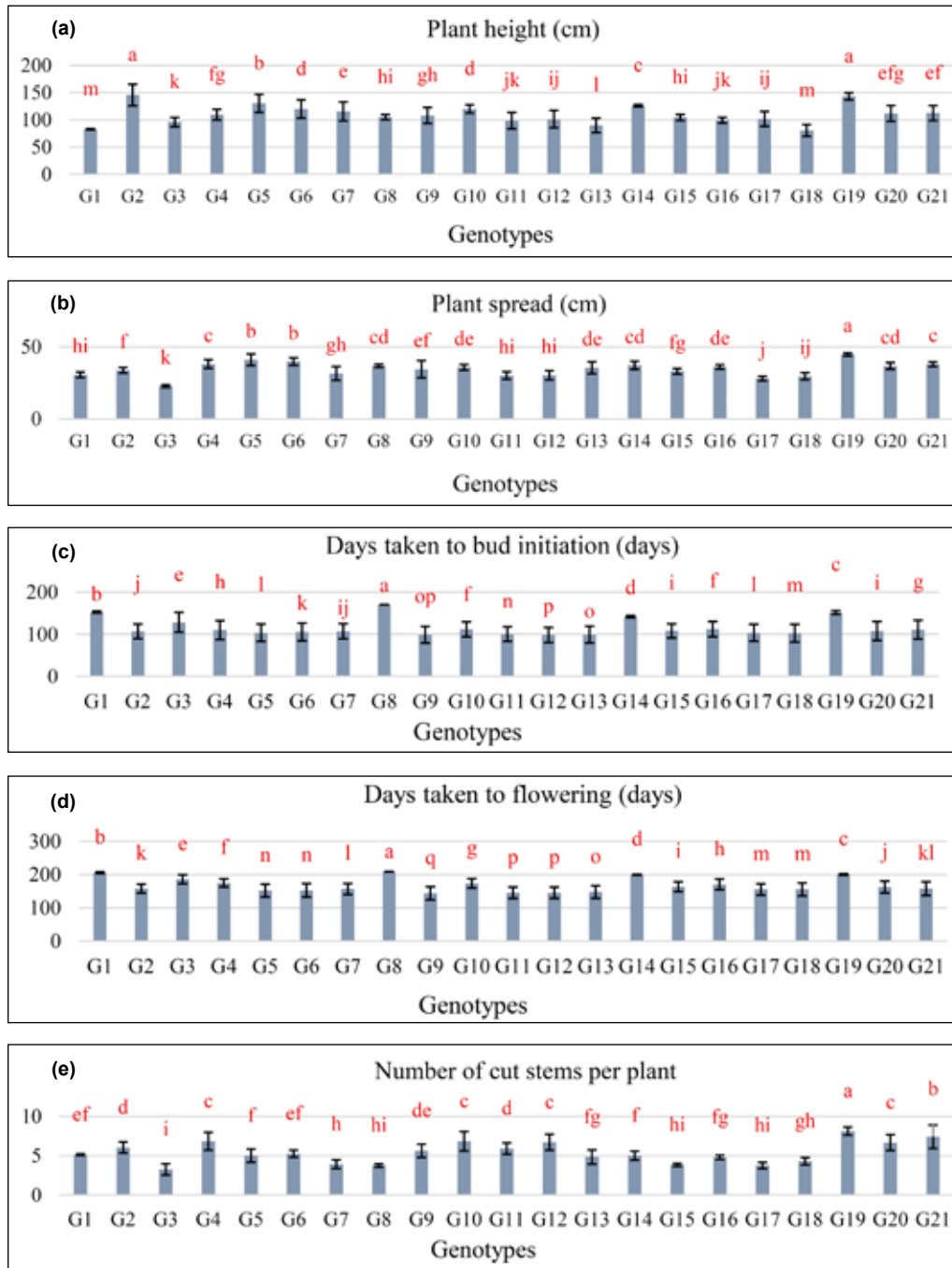


Fig. 2. Effect of photoperiodic conditions plant height (2a) plant spread (2b), days to bud initiation (2c), days to flowering (2d) and number of cut stems (2e) of chrysanthemum genotypes.

The number of days required for bud initiation was considerably lower under the controlled photoperiod (78.81 days) than under the natural photoperiod (152.82 days). Among the genotypes, the earliest bud initiation was observed in 'UHFSCChr-147' (98.29 days), while the latest was recorded in 'UHFSCChr-142' (170.58 days) (Fig. 2c). Similarly, flowering occurred earlier under the controlled photoperiod (136.07 days) than under the natural photoperiod (198.68 days). 'UHFSCChr-143' showed the earliest flowering (143.75 days), whereas 'UHFSCChr-142' recorded the latest flowering (209.17 days) (Fig. 2d). The acceleration of bud initiation and flowering under controlled short-day conditions can be explained by photoperiod-mediated induction of the reproductive phase. The onset of reproductive development redirects assimilates towards flower bud initiation and development, thereby reducing the duration of vegetative growth. Comparable genotypic variations in flowering response have been reported by Dhiman and Sehgal (5), Patil *et al.* (15), Dutta and Gupta (8), Dhiman *et al.* (4), Abrol *et al.* (1) and Singh and Bala (19). However, Dutta and Gupta (8) also observed delayed flowering in certain genotypes under controlled photoperiods, which was attributed to "Heat delay" as described by Shibata (18). Heat delay is an important constraint in year-round chrysanthemum cultivation, particularly under blackout conditions when high temperatures prevail (Furuta and Nelson, 9).

The number of cut stems per plant was higher under the natural photoperiod (6.83) than under the controlled photoperiod (3.93). Among the genotypes, 'UHFSCChr-158' produced the maximum number of cut stems per plant (8.13), whereas 'UHFSCChr-136' produced the minimum (3.25) (Fig. 2e and Table 2). The reduced number of cut stems under controlled short-day conditions may be associated with the early transition from vegetative to reproductive growth, which limits the period available for vegetative branching and stem development (Dhiman *et al.*, 4). Thus, photoperiodic manipulation can influence both the timing of flowering and the production of marketable cut stems. Stem length was greater under the natural photoperiod (81.28 cm) compared with the controlled photoperiod (64.13 cm). Among the genotypes, the longest stems were recorded in 'UHFSCChr-145' (92.96 cm), while the shortest were observed in 'UHFSCChr-148' (49.37 cm). Similarly, stem weight was higher under the natural photoperiod (35.06 g) than under the controlled photoperiod (25.81 g), with the maximum stem weight recorded in 'UHFSCChr-135' (45.17 g) and the minimum in 'UHFSCChr-160' (22.02 g). The greater stem length and weight under natural photoperiods may be attributed

to prolonged vegetative growth and greater assimilate accumulation before reproductive transition. The onset of the reproductive phase redirects assimilates towards flower bud initiation and development, which may reduce the resources available for further stem elongation and biomass accumulation under controlled short-day conditions (Dutta *et al.*, 7). Flower diameter was also greater under the natural photoperiod (5.79 cm) than under the controlled photoperiod (4.93 cm). Among the genotypes, the maximum flower diameter was recorded in 'UHFSCChr-134' (8.88 cm), whereas the minimum was observed in 'UHFSCChr-156' (3.27 cm) (Table 1 and Table 2). The greater flower diameter under natural conditions may be associated with enhanced petal elongation resulting from intensified sink activity during flower development (Dutta *et al.*, 7). These genotypic differences further indicate the importance of genetic background in determining flower size and its response to photoperiod.

The number of flowers per stem was higher under the natural photoperiod (12.14) compared with the controlled photoperiod (9.58). 'UHFSCChr-156' produced the highest number of flowers per stem (17.92), whereas 'UHFSCChr-136' produced the lowest (3.92) (Table 1 and Table 2). The greater number of flowers per stem under natural photoperiods may be related to the longer vegetative phase and sufficient time for carbohydrate accumulation, which supports proper bud differentiation and subsequent flower development (Palai *et al.*, 14). Similar variations in growth and flowering attributes among chrysanthemum genotypes under different photoperiodic conditions have been reported by Dhiman and Sehgal (5), Patil *et al.* (15), Dutta and Gupta (8), Dhiman *et al.* (4), Abrol *et al.* (1) and Singh and Bala (19). Flowering duration was greater under the natural photoperiod (29.85 days) than under the controlled photoperiod (23.57 days). Among the genotypes, the longest flowering duration was recorded in 'UHFSCChr-147' (34.63 days), while the shortest was observed in 'UHFSCChr-145' (21.04 days). Similarly, vase life was longer under the natural photoperiod (12.85 days) compared with the controlled photoperiod (10.31 days). The maximum vase life was recorded in 'UHFSCChr-142' (18.92 days), whereas the minimum was observed in 'UHFSCChr-137' (7.92 days) (Table 1 and Table 2). The shorter flowering duration under controlled short-day conditions may be associated with the earlier transition to reproductive growth, which reduces the duration of vegetative development and may influence subsequent flower longevity. In contrast, plants maintained under natural photoperiods undergo prolonged vegetative growth, which may facilitate the development of stronger stems and

Table 1: Variation in genotypes due to photoperiodic conditions.

G	Length of cut stem (cm)	Weight of cut stem (g)	Number of flowers per stem	Flower diameter (cm)	Duration of flowering (days)	Vase life (days)
G1	74.68 ± 0.63 ^e	40.66 ± 0.50 ^b	5.29 ± 0.08 ^j	8.88 ± 0.19 ^a	30.33 ± 0.34 ^c	16.58 ± 0.88 ^b
G2	83.51 ± 1.57 ^c	45.17 ± 4.30 ^a	11.08 ± 0.49 ^f	7.26 ± 0.32 ^b	30.92 ± 2.69 ^c	14.88 ± 2.82 ^c
G3	75.93 ± 4.54 ^e	27.80 ± 1.13 ^{ji}	3.92 ± 0.14 ^k	6.66 ± 0.31 ^c	25.12 ± 1.52 ^j	16.50 ± 0.34 ^b
G4	69.18 ± 5.74 ^g	24.65 ± 1.66 ^j	8.46 ± 0.66 ^{hi}	4.72 ± 0.14 ^g	25.79 ± 0.85 ^{hi}	17.62 ± 0.62 ^a
G5	84.90 ± 5.73 ^c	32.61 ± 1.54 ^{ef}	16.54 ± 0.75 ^b	5.01 ± 0.14 ^f	26.79 ± 1.22 ^{fg}	9.58 ± 0.58 ^j
G6	78.08 ± 7.24 ^d	29.18 ± 1.50 ^{ghi}	16.88 ± 0.83 ^b	5.00 ± 0.08 ^f	25.25 ± 1.51 ⁱ	11.67 ± 0.19 ^g
G7	72.68 ± 7.59 ^f	25.63 ± 2.67 ^{kl}	9.50 ± 0.47 ^g	4.62 ± 0.07 ^g	23.38 ± 1.48 ^k	10.88 ± 0.29 ^h
G8	84.12 ± 0.87 ^c	34.73 ± 0.36 ^d	9.83 ± 0.27 ^g	4.80 ± 0.05 ^g	29.46 ± 0.14 ^d	10.29 ± 0.37 ⁱ
G9	70.66 ± 7.07 ^g	31.10 ± 6.26 ^{fg}	13.21 ± 2.42 ^{de}	4.13 ± 0.15 ^j	26.17 ± 1.95 ^{gh}	11.38 ± 0.24 ^g
G10	92.96 ± 6.49 ^a	29.32 ± 2.28 ^{ghi}	9.92 ± 0.61 ^g	5.08 ± 0.18 ^f	21.04 ± 1.07 ⁱ	10.42 ± 0.47 ⁱ
G11	59.00 ± 0.94 ^j	32.45 ± 1.32 ^{ef}	4.96 ± 0.21 ^j	6.71 ± 0.21 ^c	32.58 ± 2.43 ^b	12.12 ± 0.84 ^f
G12	61.10 ± 1.85 ^j	33.08 ± 1.90 ^{de}	5.17 ± 0.25 ^j	6.70 ± 0.17 ^c	34.62 ± 2.42 ^a	14.25 ± 0.30 ^d
G13	49.37 ± 1.54 ^k	31.59 ± 3.51 ^{ef}	17.17 ± 1.10 ^{ab}	4.41 ± 0.22 ^b	21.50 ± 1.38 ^j	10.42 ± 1.42 ^j
G14	87.39 ± 1.30 ^b	30.70 ± 1.69 ^{gh}	9.54 ± 0.63 ^g	6.37 ± 0.38 ^d	24.21 ± 0.39 ^j	10.92 ± 0.69 ^h
G15	61.18 ± 4.39 ^j	26.81 ± 1.70 ^{jk}	13.71 ± 0.33 ^d	4.36 ± 0.19 ^b	25.33 ± 1.14 ^j	13.21 ± 2.52 ^e
G16	83.60 ± 2.72 ^c	26.82 ± 3.05 ^k	7.79 ± 0.34 ^j	3.80 ± 0.41 ^j	26.21 ± 2.26 ^{gh}	8.96 ± 0.37 ^{kl}
G17	61.61 ± 5.10 ^j	28.99 ± 1.86 ^{hi}	12.33 ± 1.22 ^e	3.72 ± 0.19 ^j	26.33 ± 2.06 ^{gh}	8.12 ± 0.11 ^m
G18	57.04 ± 5.23 ^j	37.53 ± 3.40 ^c	17.92 ± 0.58 ^a	3.26 ± 0.17 ^k	27.21 ± 2.04 ^f	9.17 ± 0.42 ^{jk}
G19	84.38 ± 2.02 ^c	25.56 ± 1.72 ^{kl}	14.96 ± 1.49 ^c	6.32 ± 0.19 ^d	28.21 ± 0.44 ^e	8.50 ± 0.35 ^{lm}
G20	65.60 ± 3.70 ^h	22.67 ± 1.51 ^m	9.00 ± 0.32 ^{gh}	4.77 ± 0.29 ^g	23.00 ± 1.30 ^k	8.58 ± 0.12 ^{lm}
G21	69.85 ± 5.61 ^g	22.02 ± 1.34 ^m	10.88 ± 0.60 ^f	5.94 ± 0.20 ^e	27.50 ± 1.58 ^f	9.08 ± 0.15 ^k

greater assimilate reserves, thereby contributing to improved postharvest performance and vase life (Pathania, 16). The observed genotypic differences in flowering duration and vase life may be attributed to

Table 2: Showing variation among different photoperiodic treatments.

Parameters	Natural photoperiod	Controlled photoperiod
Plant height	134.16 ± 2.94 ^a	85.07 ± 2.31 ^b
Plant spread	40.07 ± 0.75 ^a	29.03 ± 0.71 ^b
Days taken to bud initiation	152.82 ± 1.27 ^a	78.81 ± 4.45 ^b
Days taken to flowering	198.67 ± 1.12 ^a	136.07 ± 4.37 ^b
Number of cut stems per plant	6.83 ± 0.26 ^a	3.93 ± 0.14 ^b
Length of cut stem	81.28 ± 1.63 ^a	64.13 ± 1.59 ^b
Weight of cut stem (g)	35.06 ± 0.88 ^a	25.81 ± 0.76 ^b
Number of flowers per stem	12.14 ± 0.63 ^a	9.58 ± 0.48 ^b
Flower diameter (cm)	5.79 ± 0.18 ^a	4.93 ± 0.17 ^b
Duration of flowering	29.85 ± 0.53 ^a	23.57 ± 0.43 ^b
Vase life (days)	11.78 ± 0.47 ^a	11.37 ± 0.43 ^b

inherent varietal characteristics and their differential responses to photoperiodic conditions. Similar variations in flowering duration have been reported by Dhiman and Sehgal (6), Patil *et al.* (15), Sangma *et al.* (17), Dhiman *et al.* (4) and Abrol *et al.* (1). Comparable findings regarding flowering duration and vase life have also been documented by Sangma *et al.* (17). Overall, the results demonstrate that photoperiodic manipulation substantially alters the balance between vegetative growth and reproductive development in chrysanthemum, with controlled short-day conditions promoting earlier bud initiation and flowering, whereas natural photoperiods favoured vegetative growth, stem development, flower size, flower number, flowering duration and vase life.

The present study demonstrated significant variation among chrysanthemum genotypes under natural and controlled photoperiodic conditions. Natural photoperiod proved more favourable for enhancing vegetative growth, stem quality and floral yield, whereas controlled photoperiod successfully promoted earlier bud initiation and flowering with only a marginal reduction in yield. Several genotypes

exhibited a response group of less than 16 weeks, indicating strong potential for off-season production. These findings highlight the potential of photoperiod manipulation as a practical tool for regulating crop schedules and ensuring off-season flower availability. The identified variability among genotypes can serve as a valuable resource for breeding programs and for developing region-specific production strategies to strengthen year-round chrysanthemum cultivation and improve grower profitability.

AUTHOR'S CONTRIBUTION

Conceptualization of research (SRD); designing of the experiments (AG, SRD, MB, NS, RKG); contribution of experimental materials (SRD); data collection (AG) analysis of data and interpretation (RKG); preparation of the manuscript (AG and GK).

DECLARATION

The authors declare that there is no conflict of interest.

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