



RESEARCH ARTICLE

Genotypic variability in chrysanthemum (*Dendranthema grandiflora* Tzvelev) under different photoperiodic treatments

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Abstract

The floriculture industry increasingly requires chrysanthemum cultivars with diverse blooming periods to ensure reliable off-season production. Accordingly, 21 genotypes were evaluated in the year 2023 under natural and controlled photoperiodic regimes in a naturally ventilated polyhouse, using a factorial randomized block design (FRBD) with three replications. Among the genotypes, the earliest colour bud initiation (133.29 days) was recorded in UHF5Chr-143, which also produced the highest number of shoots per plant (3.83). The maximum number of cut flower stems per square meter (284.38) was obtained from UHF5Chr-158, while the highest number of flowers per plant (132.08) and the heaviest single flower (5.69 g) were observed in UHF5Chr-158 and UHF5Chr-134 respectively. Across photoperiodic regimes, higher yields were achieved under the natural photoperiod, with averages of 3.36 shoots per plant, 87.61 flowers per plant, 227.49 cut stems per square meter and a single-flower weight of 2.02 g. In contrast, the controlled photoperiod significantly advanced colour bud initiation (124.57 days) and flowering, with yields slightly lower than under natural conditions. Nonetheless, by enabling off-season production, controlled photoperiod offers a significant commercial advantage, as reduced yields can be offset by higher market prices. Overall, the study demonstrated substantial genotypic variability in growth and floral attributes. Natural photoperiod favoured vegetative growth and qualitative traits, whereas controlled photoperiod optimized flowering schedules while retaining sufficient yield levels, thereby enhancing production planning and profitability in off-season markets.

Keywords: *Dendranthema*; genotypic variability; off-season; photoperiod; plant physiology

Introduction

Chrysanthemum (*Dendranthema grandiflora* Tzvelev), belonging to the family Asteraceae, is one of the most important commercial flower crops, cultivated extensively for cut and loose flowers as well as for pot mums (1). Native to the Northern Hemisphere, particularly Europe and Asia, it is popularly known as the “Queen of the East”, “Autumn Queen”, “Guldaudi” in India and “Mum” in the United States (2).

The crop is highly valued due to its wide variety of cultivars, beautiful colours, long vase life and extreme adaptability under various agro-climatic conditions. Perennial statistics indicate that chrysanthemum is grown on approximately 42.63 thousand hectares in India, with a yield of

684.13 thousand tonnes, consisting of 644.94 thousand tonnes of loose flowers and 39.19 thousand tonnes of cut flowers (3). Karnataka stands first with 258.15 thousand tonnes, followed by Tamil Nadu (207.13 thousand tonnes) and Andhra Pradesh (130.97 thousand tonnes). In Himachal Pradesh, chrysanthemum grows on 95.66 hectares, of which 73.86 hectares are covered by loose flowers and 21.80 hectares by cut flower production (4). These statistics highlight the economic and cultural importance of chrysanthemum in Indian floriculture.

Chrysanthemum is a qualitative short-day, highly photosensitive crop requiring long days for vegetative growth and short days for floral initiation (5). Photoperiod regulation is a key strategy enabling year – round production beyond the

natural flowering season. Commercial growers have been able to coordinate flowering with market demand through practices such as artificial lighting, blackout systems, nutrient management and utilization of better genotypes. This flexibility has significantly improved the crop's utility and market value.

Even with the existence of several superior cultivars, there is still a good market for new genotypes with varied flowering behaviour, improved ornamental value and broader adaptability under a range of growing conditions. With this perspective, the current research was conducted to assess the performance of chrysanthemum genotypes under controlled

conditions with the ultimate goal of selecting promising types for off-season flower production. The results are anticipated to contribute to crop diversification, enhanced farmer income and a consistent supply of quality flowers to meet the growing demands of the floricultural industry.

Material and Methods

Study area

The present investigation was carried out in 2023 at the Research Farm of the Department of Floriculture and Landscape

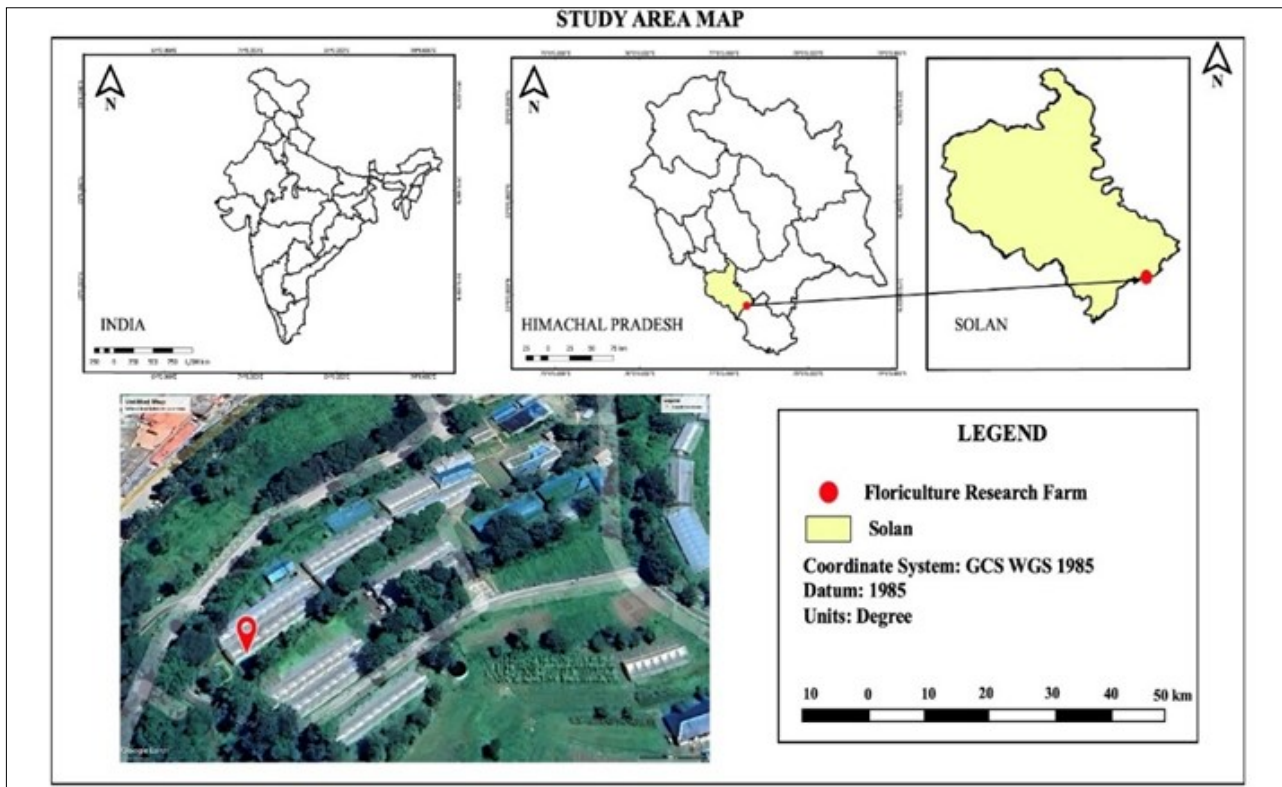


Fig. 1. Location of floriculture research farm (The study area map was created with Google Earth Pro).

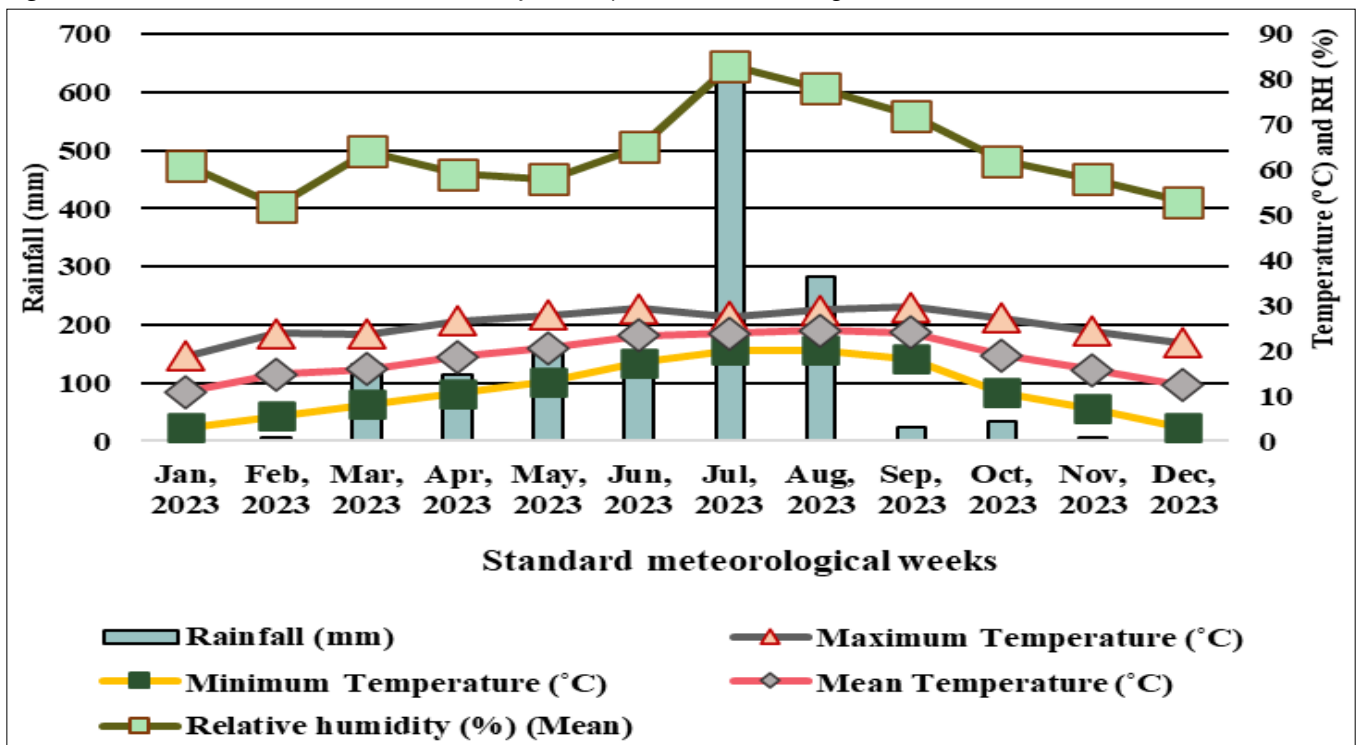


Fig. 2. Mean monthly meteorological data of research location.

Architecture, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) (Fig. 1). The experiment was conducted in a naturally ventilated polyhouse located at an altitude of 1276 m above mean sea level (30°51'0" N, 77°11'30" E), characterized by a sub-temperate to subtropical climate. Meteorological data as recorded during the crop growth period are shown in Fig. 2.

Experimental layout and statistical analysis

The study comprised 21 genotypes and two photoperiodic treatments. The experimental design followed was based on factorial randomized block design (FRBD). Each treatment combination was replicated thrice. For comparing main effects and their interaction effect, Duncan's multiple range test was used at a level of significance $p < 0.05$. Data were analysed using RStudio (version 2025.05.0+496) (6).

Photoperiodic treatments

Two photoperiodic treatments were imposed: natural photoperiod and controlled photoperiod.

Genotypes

A set of 21 chrysanthemum genotypes were utilized in this study. These are newly developed open-pollinated selections from the ongoing chrysanthemum improvement program at UHF, Solan (H.P.). The genotypes were selected based on their outstanding ornamental traits, including novel and attractive flower colours, desirable flower shapes, uniform plant architecture and better flower longevity on plants. Additionally, these selections exhibited healthy and vigorous growth, improved marketable quality and greater consumer appeal. Due to their strong potential for commercial exploitation, these genotypes were chosen for further evaluation under field conditions. Genotypes listed as: UHF5Chr-134/G1, UHF5Chr-135/G2, UHF5Chr-136/G3, UHF5Chr-137/G4, UHF5Chr-138/G5, UHF5Chr-140/G6, UHF5Chr-141/G7, UHF5Chr-142/G8, UHF5Chr-143/G9, UHF5Chr-145/G10, UHF5Chr-146/G11, UHF5Chr-147/G12, UHF5Chr-148/G13, UHF5Chr-149/G14, UHF5Chr-152/G15, UHF5Chr-153/G16, UHF5Chr-155/G17, UHF5Chr-156/G18, UHF5Chr-158/G19, UHF5Chr-159/G20 and UHF5Chr-160/G21.

Preparation of planting material

Rooted cuttings of 21 were prepared between 26-28 March from disease-free and healthy mother plants during early morning hours (05:00-08:00 hr). Cuttings (5-7 cm long) were treated with a 30 min immersion in a solution containing mancozeb (0.20 %) and carbendazim (0.10 %). The lower leaves were trimmed and the cut was made just below the node. Basal ends were also treated with naphthalene acetic acid (NAA) (500 ppm) through quick-dip method prior to sowing in pro-trays containing cocopeat. Pro-trays were kept in trenches (45 cm deep, 60 cm wide) under portable poly-sheet tunnels to provide high humidity. Trenches were irrigated with a mancozeb (0.20 %) and carbendazim (0.10 %) solution prior to placement of trays. Rooting was completed within 20 days, after which uniform rooted cuttings were transplanted on 23 April at a spacing of 20 × 15 cm, accommodating seven plants per row on 1.5 m wide beds. All genotypes were maintained in spray form (such as with lateral branches allowed to develop rather than disbudding for a single large flower).

Photoperiodic treatments

Photoperiodic control was imposed by providing artificial short-day conditions from 3 June to 15 September using portable metallic tunnels (3 × 1.5 × 1.65 m) covered with 200-micron high-density polyethylene (HDPE) sheets (7) (Fig. 3). The covers were applied daily for 16 hr (17:00 – 09:00 hr) until 60 – 70 % of flower buds on a plant exhibited visible colour, following established recommendations (8–12).

Observations recorded

From each treatment and replication, five plants were randomly selected for recording observations. The number of days taken to colour bud formation was counted from the date of planting to the stage when half or more of the flower buds showed visible colour. The number of individual flowers per plant was counted by noting all fully expanded flowers at harvest time.

Yield characteristics consisted of the number of shoots per plant, which was recorded at the time of harvest, number of cut flower stems per square meter, which was calculated by counting total harvestable stems in a unit area and the fresh weight per flower (g), which was measured at harvest by weighing individual flowers immediately after removal. Flower colour was also noted at the harvesting stage with the RHS colour chart (Royal Horticultural Society, London) (8).

Results

Variation in photoperiod treatments significantly influenced major traits in *D. grandiflora* genotypes, including days to colour bud formation, shoot number per plant, flower number per plant, cut stem density per square meter, fresh weight of individual flowers and flower colour. The time to bud colouration varied significantly among genotypes, ranging from 133.29 days in 'UHF5Chr-143' to 200.00 days in 'UHF5Chr-142' (Fig. 3A). Shoot production also differed across genotypes, with the highest mean value in 'UHF5Chr-143' (3.83) and the lowest in 'UHF5Chr-136' (2.17) (Fig. 3B). Genotypic variation was pronounced for flower production, ranging from 132.08 flowers in 'UHF5Chr-158' to only 13.38 in 'UHF5Chr-136' (Fig. 3C). Yield potential, expressed as number of cut flower stems per square meter, was highest in 'UHF5Chr-158' (270.81) and lowest in 'UHF5Chr-136' (108.33) (Fig. 3D). The fresh weight per flower ranged from 5.69 g in 'UHF5Chr-134' to 0.88 g in 'UHF5Chr-156' (Fig. 3E).

Controlled photoperiod markedly reduced the time to bud colouration (124.57 days) compared with natural photoperiod (188.90 days) (Fig. 4A). The genotype × photoperiod interaction revealed the earliest bud colouration in 'UHF5Chr-148' (87.83 days) under controlled photoperiod, whereas the maximum number of days to bud colouration was observed in 'UHF5Chr-136' (204.67 days) under natural conditions. Plants under natural photoperiod developed more shoots (3.36) than those under controlled photoperiod (2.76) (Fig. 4B). The interaction effect indicated that 'UHF5Chr-143' produced the maximum shoots (4.33) in natural conditions, while the lowest value was recorded in 'UHF5Chr-136' (1.75) under controlled photoperiod.

Natural photoperiod resulted in significantly higher flower numbers (87.61) than controlled photoperiod (41.83) (Fig. 4C). The interaction effect showed that 'UHF5Chr-158' achieved the highest

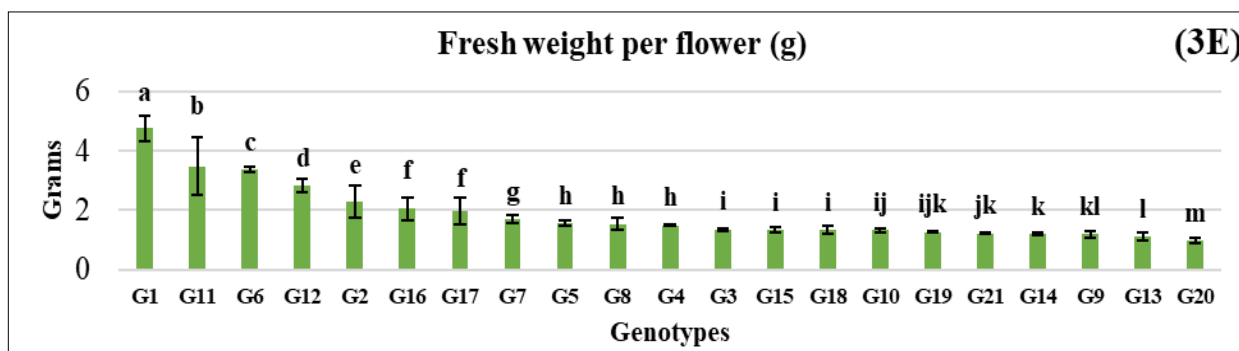
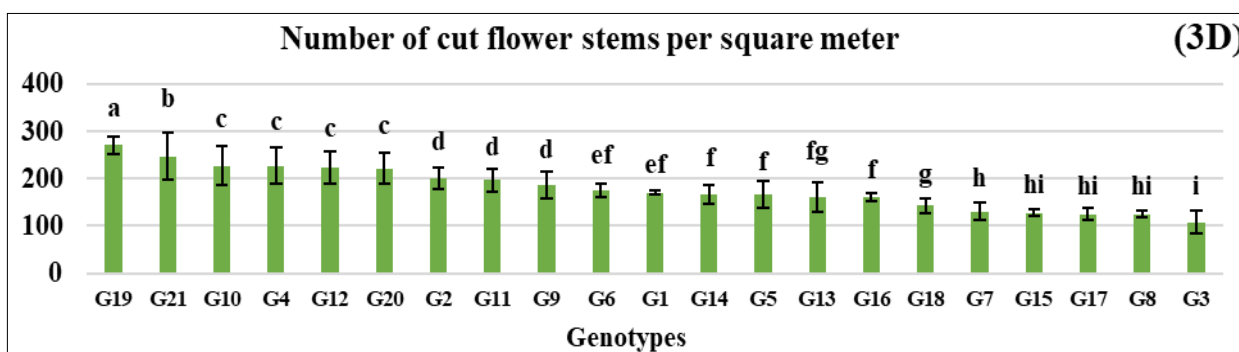
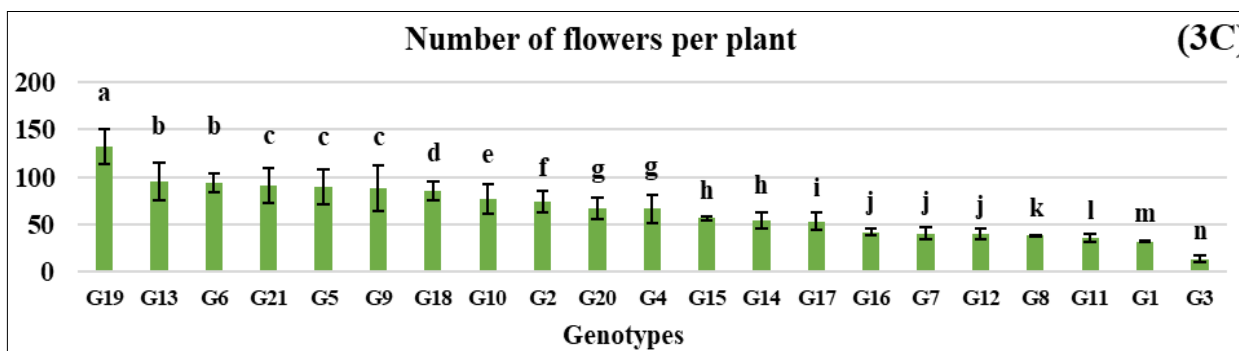
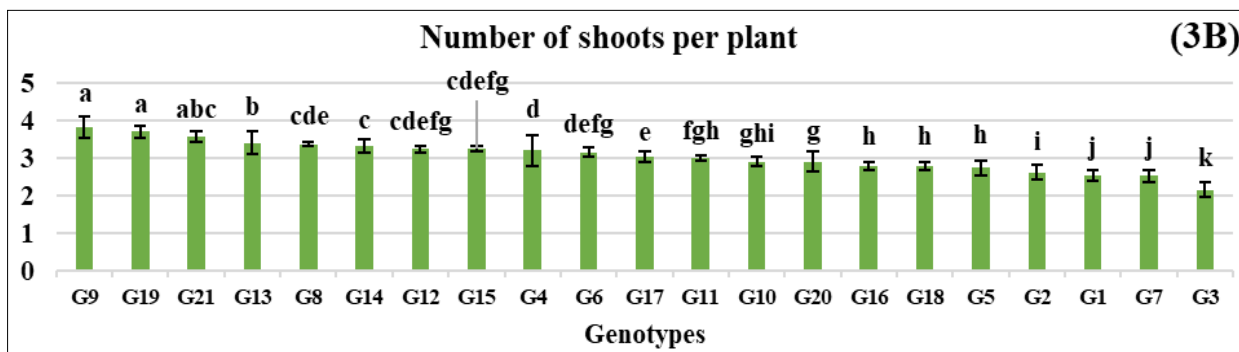
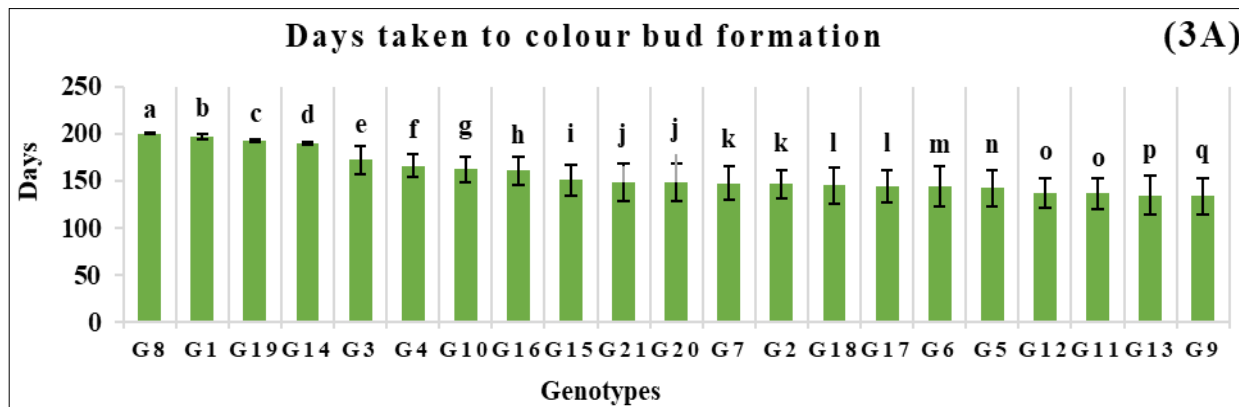


Fig. 3. Variability among chrysanthemum (*Dendranthema grandiflora* Tzvelev) genotypes under different photoperiodic treatments. (A) days to colour bud formation, (B) number of shoots per plant, (C) number of flowers per plant, (D) number of cut flower stems per square meter and (E) fresh weight per flower.

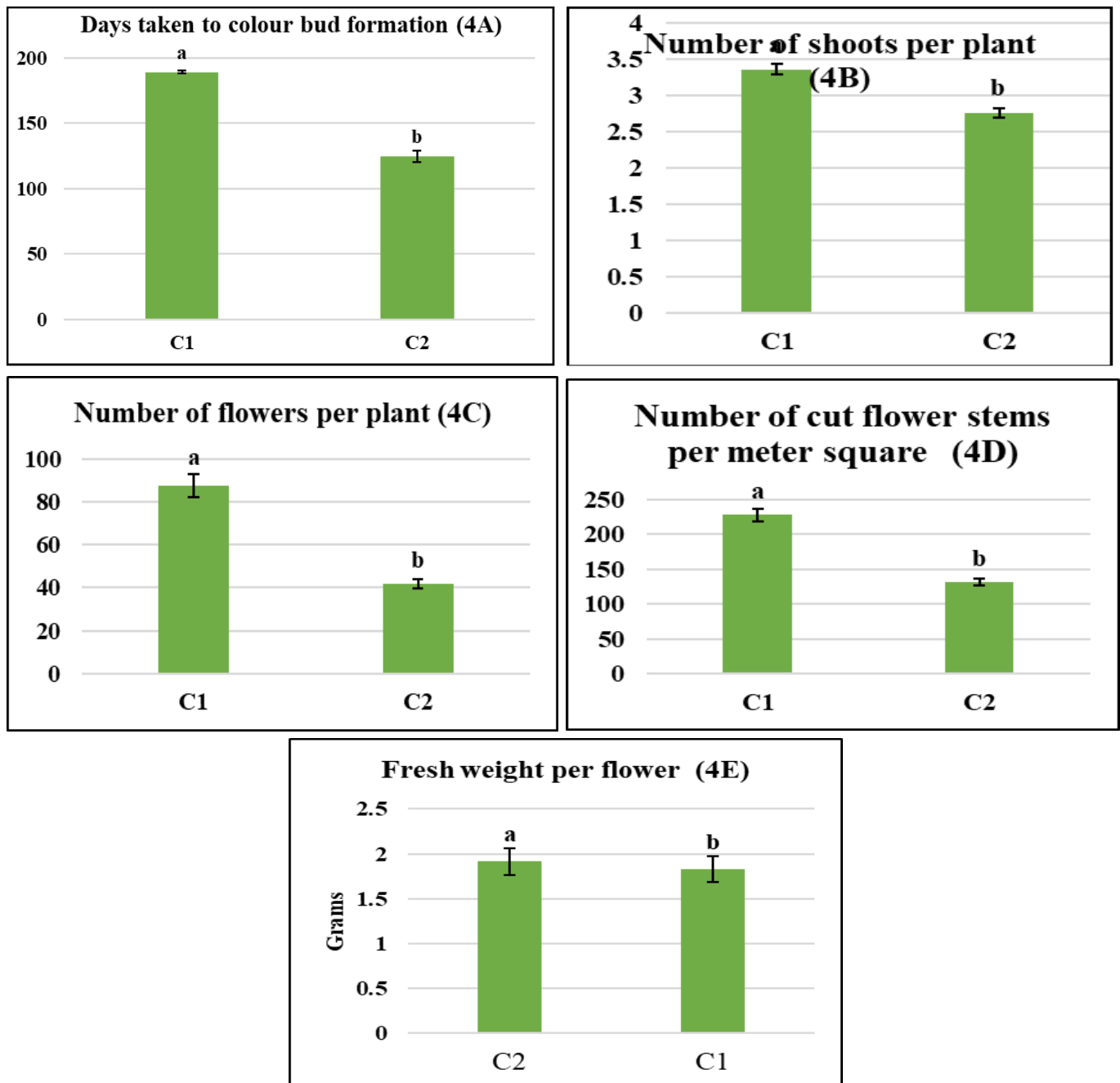


Fig. 4. Variability among different photoperiodic treatments. (A) days to colour bud formation, (B) number of shoots per plant, (C) number of flowers per plant, (D) number of cut flower stems per square meter and (E) fresh weight per flower.

flower number (173.83) under natural conditions, whereas ‘UHFSChr-136’ recorded the minimum (6.50) under controlled photoperiod. On average, natural photoperiod (227.49 stems m²) outperformed controlled photoperiod (131.07 stems m²) (Fig. 4D). A significant interaction effect was observed, with ‘UHFSChr-160’ yielding the maximum (355.52 stems m²) under natural photoperiod, while ‘UHFSChr-136’ produced the minimum (55.55 stems m²) under controlled conditions. Flowers were generally heavier under natural photoperiod (2.02 g) than controlled (1.72 g) (Fig. 4E). Interaction effects revealed that ‘UHFSChr-134’ produced the heaviest flowers under both natural (5.71 g) and controlled (5.67 g) photoperiods, with statistically similar performance. Conversely, the lowest value was recorded in ‘UHFSChr-137’ (0.78 g) under controlled photoperiod.

Most chrysanthemum genotypes maintained stable flower colour across photoperiod treatments, indicating minimal influence of day length on this trait. Minor shade variations were

recorded in a few genotypes, such as ‘UHFSChr-138’, ‘UHFSChr-143’ and ‘UHFSChr-148’ (Table 1). These changes were limited to intensity or hue shifts, suggesting overall colour stability under both natural and controlled treatment.

Correlation matrix

The Pearson’s correlation matrix revealed distinct relationships among flowering and yield-related traits (Fig. 5). The number of flowers per plant showed a strong and highly significant positive correlation with cut stems per square meter ($r = 0.72$, $**p < 0.001$) and a significant positive correlation with the number of shoots per plant ($r = 0.66$, $**p < 0.001$). Similarly, the number of shoots per plant was positively and significantly associated with cut stems per square meter ($r = 0.60$, $**p < 0.001$). Days taken to colour bud formation exhibited moderate, positive and highly significant correlations with the number of shoots per plant ($r = 0.41$, $**p < 0.001$), number of flowers per plant ($r = 0.44$, $**p < 0.001$) and cut stems per square meter ($r = 0.58$, $**p < 0.001$). In contrast, fresh

Table 1. Variation in flower colour of chrysanthemum genotypes due to photoperiodic treatments

Chrysanthemum genotypes	Photoperiodic treatments	
	Natural photoperiod	Controlled photoperiod
UHFSChr-134	White Group 155 B	White Group 155 B
UHFSChr-135	Red Purple Group 70 B	Red Purple Group 70 B
UHFSChr-136	Red Purple Group 63 C	Red Purple Group 63 C
UHFSChr-137	Bicoloured (Yellow Group 7 B and Red Group 53 B)	Bicoloured (Yellow Group 7 B and Red Group 53 B)
UHFSChr-138	Greyed-Orange Group 172 B	Greyed-Orange Group 169 A
UHFSChr-140	White Group 155 B	White Group 155 B
UHFSChr-141	White Group 155 A	White Group 155 A
UHFSChr-142	Orange Red Group 34 A	Orange Red Group 34 A
UHFSChr-143	Red Purple Group 67 C	Red Purple Group 70 D
UHFSChr-145	Yellow Orange Group 14 B	Yellow Orange Group 14 B
UHFSChr-146	Red Violet Group 81 D	Red Purple Group 63 D
UHFSChr-147	Red Violet Group 81 D	Red Purple Group 63 D
UHFSChr-148	Yellow Orange Group 21 B	Orange group 26 B
UHFSChr-149	Bicoloured (Yellow Group 9 B and Orange Red Group 34 A)	Bicoloured (Yellow Group 9 B and Orange Red Group 34 A)
UHFSChr-152	Red Purple Group 61 B	Red Purple Group 61 B
UHFSChr-153	Red Purple Group 73 B	Red Purple Group 62 D
UHFSChr-155	White Group 155 C	White Group 155 C
UHFSChr-156	Red Purple Group 73 A	Red Purple Group 65 A
UHFSChr-158	Red Purple Group 25 C	Red Purple Group 25 C
UHFSChr-159	Yellow Group 12 A	Yellow Group 12 B
UHFSChr-160	Red Purple Group 64 B	Red Purple Group 64 B

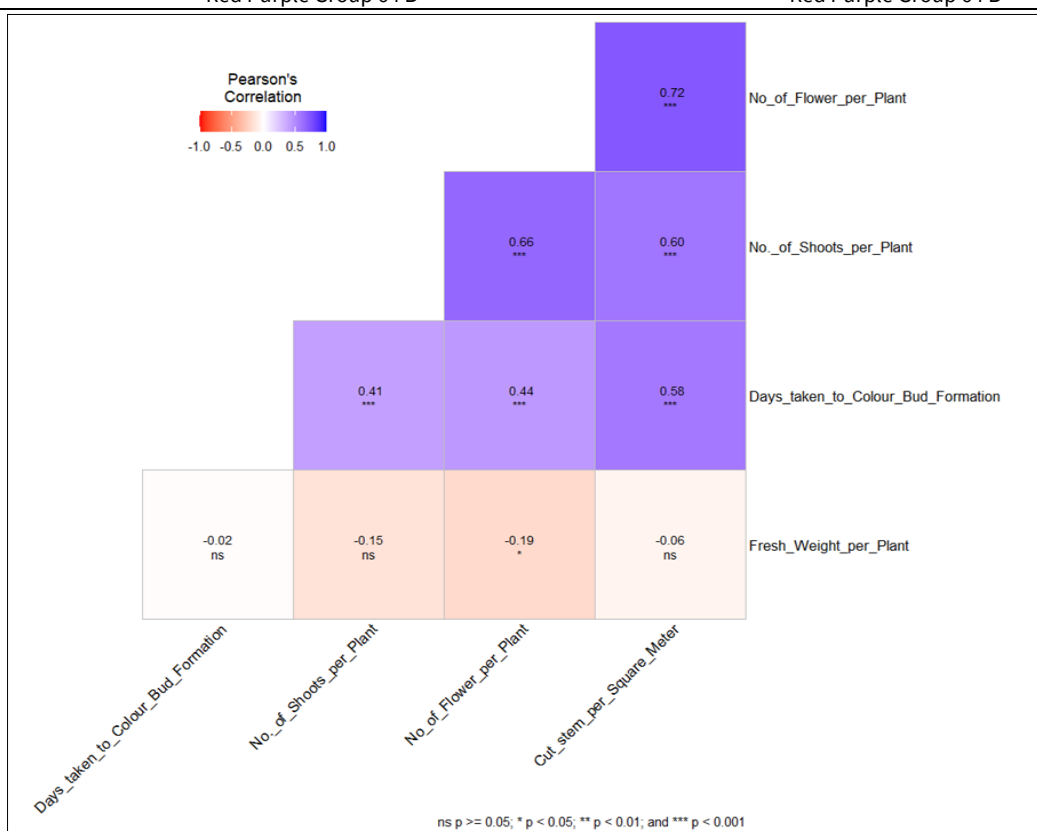


Fig. 5. Pearson's correlation matrix showing relationships among flowering and yield-related traits.

weight per plant showed weak and non-significant correlations with days taken to colour bud formation ($r = -0.02$), number of shoots per plant ($r = -0.15$), number of flowers per plant ($r = -0.19$) and cut stems per square meter ($r = -0.06$), indicating no meaningful association with flowering time or yield parameters. Overall, the correlation matrix indicates that the number of flowers per plant and the number of shoots per plant are strongly and positively associated with (cut stems per square meter), whereas fresh weight per plant shows no significant relationship with flowering or yield-related traits under the present experimental conditions.

Discussion

Differences in days to colour bud formation, number of shoots per

plant, number of flowers per plant, number of cut stems per square meter and fresh weight of single flower among genotypes can be attributed to their distinct genetic makeup. Under short-day conditions, florigen - a systemic signal synthesized in the leaves is translocated to the shoot apical meristem where it induces the transition of the vegetative meristem into an inflorescence meristem (13, 14). This conversion terminates the vegetative phase, which is otherwise sustained under long days and night breaks (15). The onset of the reproductive phase redirects assimilates toward flower bud initiation, thereby explaining the genotypic variation in days to colour bud formation, shoot number and cut stems per unit area under different photoperiods. However, it was also observed that delayed flowering in certain genotypes under controlled photoperiods was attributed to heat delay (16, 17). Heat delay is a serious constraint

in year-round chrysanthemum cultivation, particularly under blackout conditions when high temperatures prevail (18).

Similarly, differences in flower weight may be attributed to increased petal and pedicel length and number, which reflect enhanced mobilization of photosynthates to the developing flowers due to intensified sink activity (19). Furthermore, the higher number of flowers per plant observed under natural photoperiods may be associated with longer vegetative duration, allowing greater carbohydrate accumulation and consequently supporting proper bud differentiation (20). Comparable variations have been reported by several researchers (8-12, 16, 21–23).

Since changes in flower colour were slight and genotype-specific, overall colour stability was maintained. Minor shifts in flower colour may be attributed to microclimatic changes inside the blackout tunnels. Although the HDPE sheets used were white on the outside and black on the inside, they inadvertently increased night/early-morning temperatures and altered spectral quality by reducing blue and UV light. Elevated temperatures can suppress anthocyanin synthesis or accelerate pigment degradation, while altered light cues may influence pigment biosynthesis, leading to subtle hue variations.

Conclusion

Manipulation of photoperiod had a significant effect on growth and flowering dynamics, as well as productivity traits in chrysanthemum genotypes. Controlled photoperiods facilitated earlier bud initiation and successfully enabled off-season flowering, thereby extending the production window. Productivity was comparatively lower under managed conditions than under natural day lengths, yet the premium prices commanded by off-season flowers ensured economic viability. This offers growers enhanced opportunities for sustained income generation and year-round production. Natural photoperiods, on the other hand, favoured higher vegetative growth and productivity, highlighting their role in meeting bulk market demands. The distinct responses observed among genotypes underscore the importance of screening and promoting cultivars suited to specific photoperiodic regimes. Such targeted selection will enhance the resilience, adaptability and profitability of chrysanthemum cultivation across diverse production environments.

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Authors' contributions

The study was conceptualized by SRD. Data curation, formal analysis and investigation were carried out by AG. The methodology was developed by SRD, MB, NS and AG, while project administration was managed by SRD. Software development and analysis support were provided by AG, VG and AD. Supervision of the research was undertaken by SRD and MB. The original draft of

the manuscript was prepared by AG, NS, SB and AHS and review and editing of the manuscript were conducted by AG.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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