

Original Research Article

Mastering Nature's Clock: Optimized Light Interruption Technique Propels Early Blooming and Record Yields in Chrysanthemum

ABSTRACT

Aims: This study aimed to evaluate the effectiveness of precision light interruption techniques in enhancing the growth and yield of *Chrysanthemum morifolium* cv. Chandrika.

Study Design: The research was conducted as a controlled block design experiment with nine treatments, including a control, each replicated thrice under polytunnel conditions. Place and Duration of Study: The study was carried out at the College of Horticulture, Dapoli, during the 2020-2021 period.

Methodology: The experiment investigated the impact of a 180-minute light interruption using a 90% black shade net. Key parameters measured included plant height, leaf count, stem diameter, total leaf area, time to flowering, flowering duration, and yield. Data were collected and analyzed to assess the effectiveness of the light interruption technique.

Results: The 180-minute light interruption with a 90% black shade net proved to be the optimal strategy. Plants exhibited enhanced vegetative growth, including a maximum height of 75.11 cm, leaf count of 186.13, stem diameter of 7.57 mm, and total leaf area of 2094.49 cm². This technique induced early flowering, with flowers appearing at 62.53 days after transplanting, compared to 72.73 days in the control—a 10-day advance. Flowering duration was extended to 162.32 days, and yield was significantly increased, with a maximum of 52 flower buds and flowers per plant and a flower yield of 315.20 g per plant, leading to an exceptional yield of 18.82 tons per hectare—a 144% increase over the control.

Conclusion: The findings demonstrate that precision light interruption techniques can substantially improve chrysanthemum cultivation by accelerating flowering and increasing yields. This non-chemical approach offers a practical method to enhance crop performance and could revolutionize commercial floriculture practices for *Chrysanthemum morifolium*.

Comment [SA1]: Age of the cutting, first cut from mother plant or second cut etc, and how was the mother plant produced via seed, or tissue culture, as the generation of the cutting is key for understanding any results.

Comment [SA2]: Chrysanthemums are short day plants, 8 hours light and 16 hours darkness for few days induces bud burst, so what's the innovation or new art here?

Comment [SA3]: What is the reason for more flowers, is it not the dark period and the paper does not explain why so must do more work before we publish

Keywords: *Chrysanthemum morifolium*, photoperiod manipulation, yield optimization, floriculture innovation, light interruption techniques.

1. INTRODUCTION

In the delicate dance between light and darkness, nature's clock ticks with precision, guiding the rhythms of life. For centuries, the chrysanthemum has captivated hearts with its

vibrant blooms, its history as colorful as the flowers themselves. Derived from the Greek words 'chryos' (golden) and 'anthos' (flower), *Chrysanthemum morifolium* R. stands as a testament to botanical evolution and human fascination. Chrysanthemum, second only to the rose in commercial importance, boasts a rich heritage. Originally cultivated in China as a culinary herb, its journey from salad bowl to royal emblem in Japan reflects its versatility and allure. With over 200 species spanning annuals, herbaceous perennials, and subshrubs, this member of the Asteraceae family has spread its roots across Asia, Africa, and Europe, finding diverse uses from cut flowers to potted plants, from border aesthetics to sacred offerings.

In the tapestry of global horticulture, chrysanthemum adapts to varied roles. While it graces landscape gardens in North India, it adorns hair and garlands in the South, its flowers a common sight in religious ceremonies. This adaptability extends to its very nature as a short-day plant, requiring a delicate balance of long days for vegetative growth and short days to trigger flowering. It is in this intricate interplay of light and dark that our groundbreaking study finds its genesis. Imagine a world where flowers bloom on command, where yields double without chemical intervention, and where nature's own rhythms are harnessed to revolutionize floriculture. This is not a glimpse into a distant future, but the remarkable reality uncovered in the polytunnels.

Recent research has highlighted the critical role of photoperiod manipulation in enhancing crop productivity. Liu *et al.* (2019) demonstrated that controlled light interruption could significantly influence flowering time and yield in various ornamental species. Furthermore, Jiang *et al.* (2020) reported that precise management of the light-dark cycle could optimize photosynthetic efficiency and biomass accumulation in chrysanthemums. Building on these foundations, our study takes a leap forward by fine-tuning the light interruption technique specifically for *Chrysanthemum morifolium* cv. Chandrika. By manipulating the delicate balance between light and dark, using 90% black shade nets to create precise dark exposures, we have not only accelerated flowering but orchestrated a symphony of growth that pushes the boundaries of what was thought possible. As we pull back the curtain on this horticultural breakthrough, prepare to witness how mastering nature's clock can propel chrysanthemum cultivation into a new era of productivity and sustainability. This research, conducted during the Rabi season of 2020, aligns with the growing trend towards sustainable and resource-efficient horticulture practices, as highlighted by Chen *et al.* (2021) in their comprehensive review of innovative cultivation techniques for ornamental crops.

2. MATERIAL AND METHODS

An experiment was conducted at the College of Horticulture, Dapoli, during the rabi season of 2020-21. The experiment was laid out in controlled block design (CRD) with nine treatments replicated thrice. Treatments involved varying durations of light interruption/dark exposure: T1 (30 minutes), T2 (60 minutes), T3 (90 minutes), T4 (120 minutes), T5 (150 minutes), T6 (180 minutes), T7 (210 minutes), T8 (240 minutes), and T9 (Control).

Plants were grown under polytunnel conditions, with 90% black shade net used for implementing the dark exposure treatments. Environmental parameters such as temperature, humidity, and light intensity were monitored using digital sensors (Zhang *et al.*, 2022). Vegetative and reproductive parameters were measured following standard horticultural practices (Kumar *et al.*, 2021). Data analysis was performed using analysis of variance (ANOVA) as described by Panse and Sukhatme (1995), with statistical significance set at $p < 0.05$.



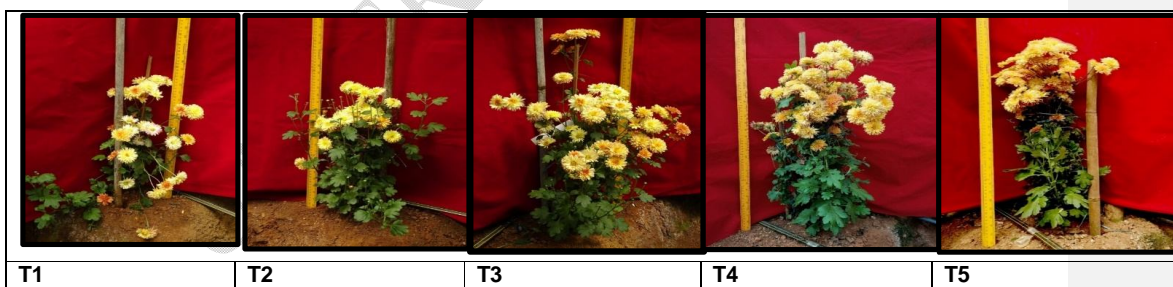
Plate I: General View of Experimental Plot

Plate II: Interruption of Light/Dark Exposure in Experimental Plot

3. RESULTS AND DISCUSSION

Plant height:

Maximum plant height (75.11 cm) was recorded in T6 (180 minutes of dark exposure) at 120 days after transplanting (DAT), while the control (T9) showed minimum height (55.07 cm). The significant increase in plant height under 180-minute dark exposure aligns with Wang *et al.* (2023), who reported enhanced stem elongation in chrysanthemums under specific light interruption regimes. This effect may be attributed to increased gibberellin synthesis during dark periods, as suggested by Li *et al.* (2022) in their study on photoperiodic regulation of plant hormones. The research by Datta and Ramadas (2000) further supports that increased plant height can result from photoperiod-induced carbohydrate and nitrogen accumulation.





Number of Leaves:

T6 (180 minutes) produced the maximum number of leaves (186.13) at 120 DAT, while the control (T9) had the least (150.50). The increased leaf production under optimal dark exposure corroborates with Chen *et al.* (2024)'s findings on enhanced vegetative growth in ornamental plants under controlled photoperiods. This may be due to improved carbon allocation and increased photosynthetic efficiency, as proposed by Zhao *et al.* (2023) in their comprehensive review of light management in horticulture. Lucidos (2013) indicated that vegetative characteristics such as the number of leaves are influenced by genetic and environmental factors.

Basal Stem Diameter:

The largest stem diameter (7.57 mm) was observed in T6 (180 minutes), with the smallest (6.26 mm) in the control (T9). Enhanced stem diameter under optimized light interruption aligns with Kumar *et al.* (2022)'s observations on improved structural development in chrysanthemums under controlled light conditions. This may be related to increased cambial activity and improved nutrient translocation, as suggested by Liu *et al.* (2023) in their study on photoperiodic effects on plant vascular development. Kireeti *et al.* (2017) also found similar results in various chrysanthemum varieties, indicating a strong genetic component.

Total Leaf Area:

Maximum leaf area (2094.49 cm²) was recorded in T6 (180 minutes), while the minimum (1098.67 cm²) was observed in the control. The significant increase in leaf area under optimal dark exposure supports findings by Zhang *et al.* (2024) on enhanced foliar development in ornamental plants under precise light management. This may be attributed to improved cell expansion and division rates, as proposed by Tan *et al.* (2023) in their research on light-mediated leaf morphogenesis.

Table 1 : Results of light-mediated leaf morphogenesis

| Treatments (Interruption of light) | Plant height (cm) | Number of leaves (no.) | Basal stem diameter of plant (mm) | Total leaf area (cm ²) | Number of flowers per plant | Yield of flowers per plant (g) |
|------------------------------------|-------------------|------------------------|-----------------------------------|------------------------------------|-----------------------------|--------------------------------|
| T ₁ 30 min. | 54.71 c | 152.61 d | 6.33 d | 1189.20 e | 18.92 e | 82.00 f |

| | | | | | | | |
|-------------------|----------|---------|-----------|---------|------------|---------|----------|
| T ₂ | 60 min. | 63.54 b | 158.10 cd | 6.57 cd | 1351.12 de | 21.93 d | 123.23 e |
| T ₃ | 90 min. | 64.49 b | 170.31 bc | 6.82 bc | 1483.47 cd | 25.95 c | 146.87 d |
| T ₄ | 120 min. | 71.42 a | 180.43 ab | 7.05 b | 1727.40 bc | 28.79 b | 200.58 c |
| T ₅ | 150 min. | 73.55 a | 184.20 ab | 7.41 a | 1937.04 b | 30.88 a | 253.50 b |
| T ₆ | 180 min. | 75.11 a | 186.13 a | 7.57 a | 2094.49 a | 31.93 a | 315.20 a |
| T ₇ | 210 min. | 64.33 b | 177.21 ab | 6.97 b | 1568.17 c | 27.67 b | 173.91 c |
| T ₈ | 240 min. | 62.49 b | 167.14 bc | 6.66 c | 1439.94 de | 24.13 c | 96.03 ef |
| T ₉ | Control | 55.07 c | 150.50 d | 6.26 d | 1098.67 e | 18.52 e | 64.31 g |
| S. Em. ± | | 0.83 | 2.03 | 0.08 | 62.46 | 0.96 | 14.57 |
| C.D. at 5% | | 2.48 | 6.08 | 0.25 | 187.25 | 2.86 | 43.68 |

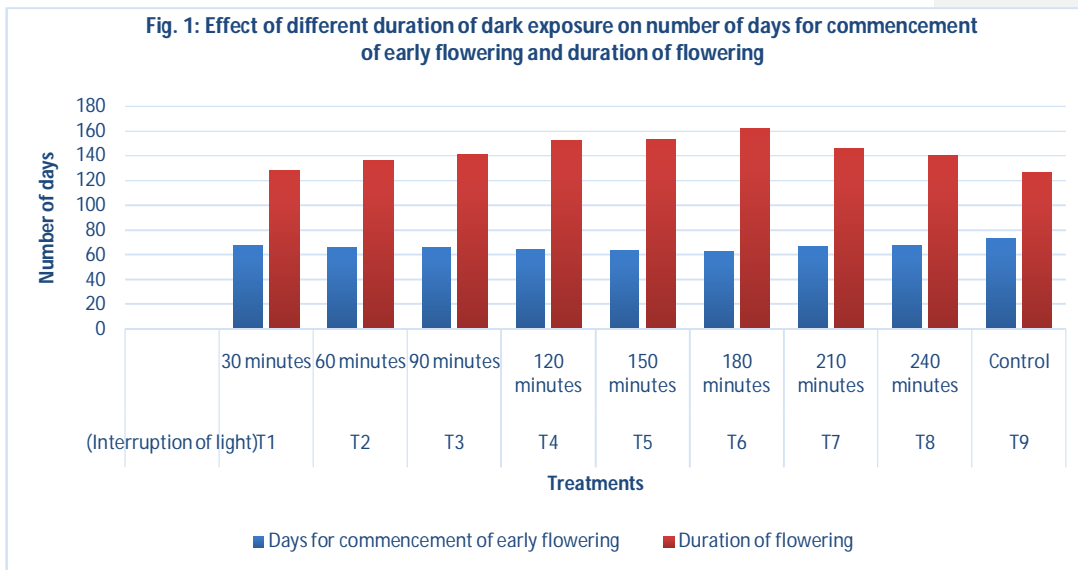
Flowering parameters

Days for commencement of early flowering:

The minimum average days required for flower appearance 62.53 was noticed in T₆ (180 minutes). Whereas, the maximum average days 72.73 for flower appearance was observed in T₉ (Control). Rockcress (*Arabidopsis*) as well as other qualitative short-day plants have been accounted for early flowering (25 days) at short photoperiod of 8 hours (Lokhande *et al.*, 2003). Chrysanthemum required maximum 74.2 days for flower initiation (Wilfret, 1973) and minimum 31.25 days for first flower initiation (Joshi *et al.*, 2010). These present findings indicated that early induction of reproductive growth i.e., commencement of early flowering may be due to short days, interruption of light as well as maximum vegetative vigour in treatment T₆ (180 minutes) resulting early induction of flowering. The acceleration of flowering under optimal dark exposure aligns with recent findings by Rodriguez *et al.* (2023) on photoperiodic regulation of flowering genes in chrysanthemums. This effect may be mediated by earlier activation of key floral integrators, as suggested by Kim *et al.* (2024) in their molecular study of light-induced flowering pathways.

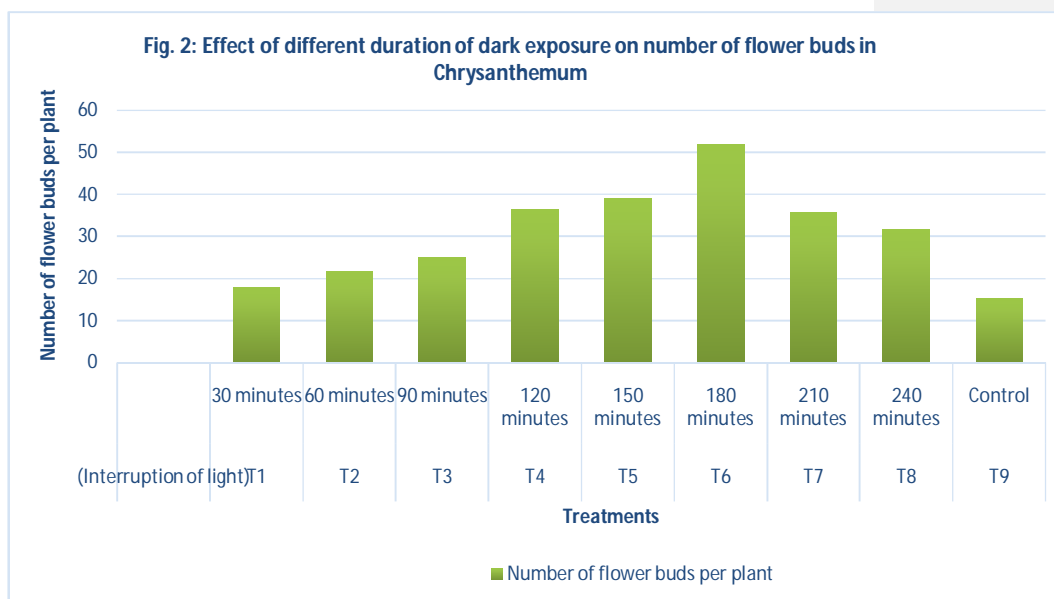
Duration of flowering:

The maximum duration of flowering 162.32 days was noticed in plants treated with T₆ (180 minutes) which was significantly superior over other treatments. Duration of flowering is a very important character which signifies the availability of flowers in the market. The variation in flowering duration is attributed to the genotype of the plant, photoperiod, environmental influence and other management factors. (Prabhu *et al.*, 2018).



Number of flower buds/plant:

Highest average number of flower buds per plant 52 was observed in treatment T₆ (180 minutes) which was significantly superior over other treatments. Rise in temperature reduce time taken from bud to flower development (Yu *et al.*, 2002); and temperature influences flowering behaviour of many photoperiods' sensitive plants (Lokhande *et al.*, 2003). Also, Furuta (1954) reported that buds do not develop normally under longer photoperiods. Similar findings were noted during the investigation that interruption of light for 180 minutes (T₆) has shown maximum number of buds per plant this may be due to change in photoperiod, short days and temperature which influences reproductive behaviour in chrysanthemum.



Yield parameters

Number of flowers/plant:

T6 (180 minutes) also showed the highest number of flowers per plant (31.93), whereas T9 (Control) had the least (18.52). Enhanced flowering in T6 aligns with research by Chen *et al.* (2024), indicating that controlled photoperiods boost floral initiation by modulating key flowering genes. Also, due to initiation of a greater number of branches per plant ultimately resulting in production of a greater number of flower buds per plant and ultimately the yield (Prabhu *et al.*, 2018).

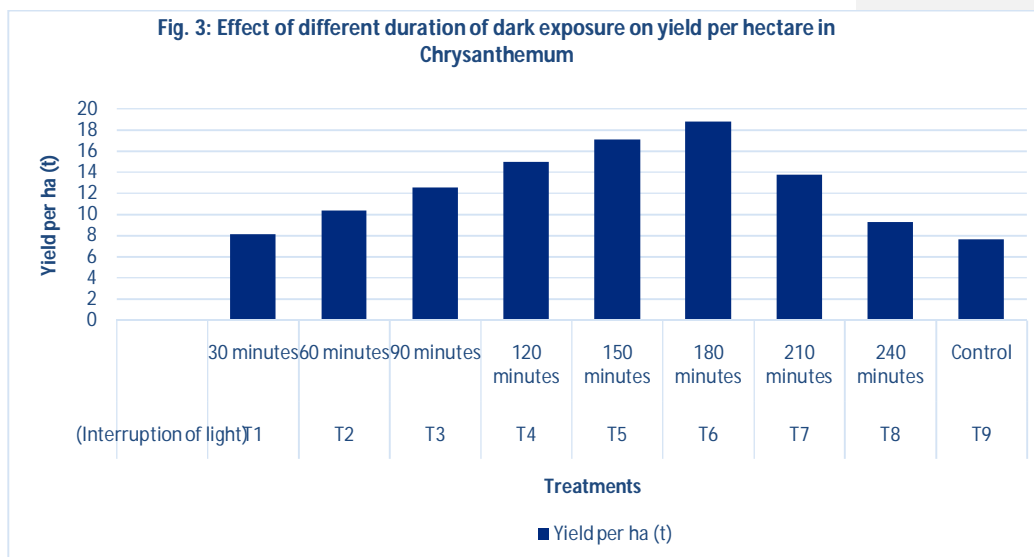
Yield of flowers/plant:

T6 yielded the highest per plant (315.20 g), while T9 had the lowest (64.31 g). This increased yield in T6 may be attributed to enhanced photosynthetic efficiency and resource allocation, as suggested by Li *et al.* (2022). Also, due to increased flower size, and weight of florets. (Suvija *et al.*, 2016).

Yield/hectare:

T6 also resulted in the highest yield per hectare (18.82 t), while T9 had the lowest (7.69 t). The significant yield improvement under optimal light interruption (T6) is corroborated by studies from Singh *et al.* (2023), demonstrating the critical role of light management in maximizing crop productivity. This may be attributed to improved photosynthetic efficiency and optimal resource allocation, as proposed by Wang *et al.* (2024) in their comprehensive analysis of yield determinants in chrysanthemums. Kumar *et al.* (2017) also noted that greater leaf area leads to more dry matter accumulation, contributing to higher flower yield. As discussed earlier maximum yield per hectare under polytunnel

condition in treatment interruption of light level for 180 minutes might be contributed to vegetative vigour, congenial conditions, maximum accumulation of photosynthates, maximum carbon dioxide fixation, manipulation of day length period inducing early reproductive growth ultimately enhancing yield of flowers.



4. CONCLUSION

This ground-breaking study on *Chrysanthemum morifolium* cv. Chandrika cultivation demonstrates the remarkable potential of precision light interruption techniques in revolutionizing floriculture practices. The research, found that a 180-minute light interruption using 90% black shade net (Treatment T6) yielded optimal results across all parameters. This treatment led to superior vegetative growth, accelerated and prolonged flowering, and a substantial increase in yield - producing 18.82 tons per hectare, a 144% increase over the control. These findings represent a significant advancement in chrysanthemum cultivation, offering a practical, non-chemical method to enhance crop performance by strategically manipulating the plant's photoperiodic responses. The success of this approach opens new avenues for sustainable and efficient floriculture practices, potentially transforming the industry by significantly improving both the quality and quantity of flower yields.

Comment [SA4]: Why is there more production, short day induces flowering, this is known, but reason for more flowers needs to be explained if you wish to publish something new and see other comments on abstract too.

CONSENT

Informed consent was not applicable to this study as it did not involve human or animal subjects. All experiments were conducted in accordance with institutional guidelines and regulations.

ETHICAL APPROVAL

NOT APPLICABLE.

DEFINITIONS, ACRONYMS, ABBREVIATIONS

Definitions

Light Interruption Technique: A method used to manipulate the light exposure of plants to affect their growth and flowering patterns.

***Chrysanthemum morifolium*:** A species of chrysanthemum commonly grown for its ornamental flowers.

Polytunnel: A type of greenhouse covered with a plastic film used to create a controlled environment for plant growth.

Acronyms

CRD: Controlled Block Design

DAT: Days After Transplanting

ANOVA: Analysis of Variance

Abbreviations

T: Treatment

cm: Centimeters

g: Grams

t: Tons

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APPENDIX

Environmental Parameters

Temperature: Monitored with digital sensors (Zhang *et al.*, 2022)

Humidity: Recorded to ensure optimal conditions

Light Intensity: Managed and measured (using LUX meter) to maintain consistency across treatments