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.
Details: The cuttings used were terminal cuttings taken from 2-month-old healthy mother plants in the adult vegetative phase. 25 days old seedlings were transplanted and subjected to light interruption (12 am to 3 am) using a 120-volt LED bulb placed 2 m above the seedlings for 20 days to delay bud initiation and promote vegetative growth.
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 cm^2. 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.While chrysanthemums are traditionally short-day plants requiring specific light-to-dark ratios to induce bud burst, this innovative approach resulted in significant improvements earlier and extended flowering, and a remarkable increase in yield due to proper vegetative growth.
Conclusion: The findings demonstrate that precision light interruption techniques can substantially improve chrysanthemum cultivation. This non-chemical approach offers a practical method to enhance crop performance.

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 ground-breaking 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).

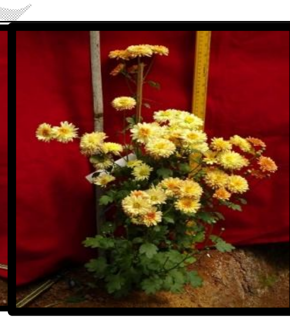
Plants were grown under polytunnel conditions, with 90% black shade net used for implementing the dark exposure treatments. Environmental parameters such as temperature, humidity, and light intensity were monitored using digital sensors (Zhang *et al.,* 2022). Vegetative and reproductive parameters were 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 2: 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.

				
T1	**T2**	**T3**	**T4**	**T5**

			
T6	**T7**	**T8**	**T9**

Plate 3 : Effect of different duration of dark exposure on growth and yield in Chrysanthemum cv. Chandrika

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

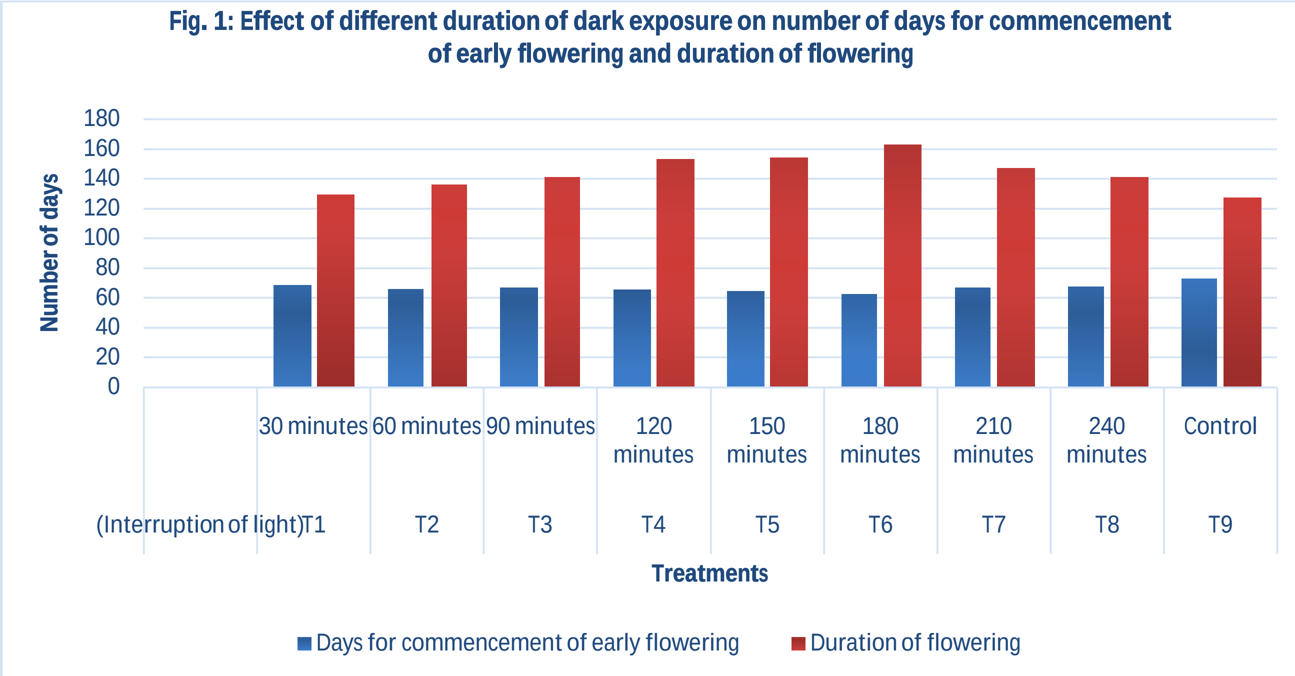
Flowering parameters

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 T_6 (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 (T_6) 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.

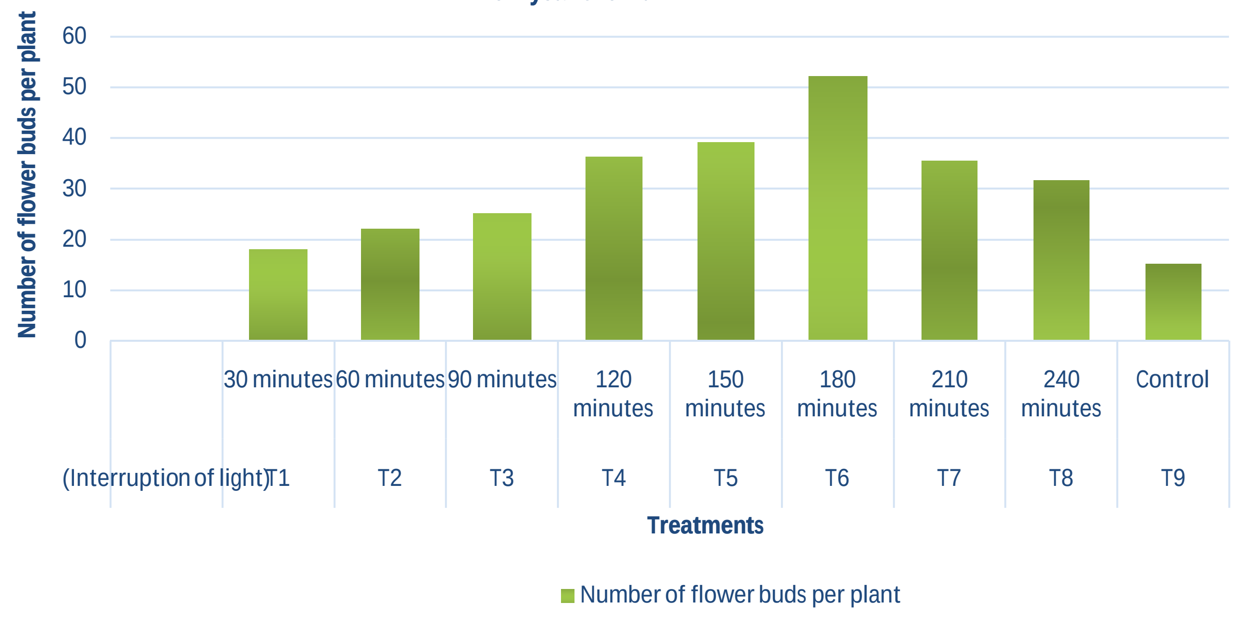


Fig. 2: Effect of different duration of dark exposure on number of flower buds in Chrysanthemum

Yield parameters

Number of flowers/plant:

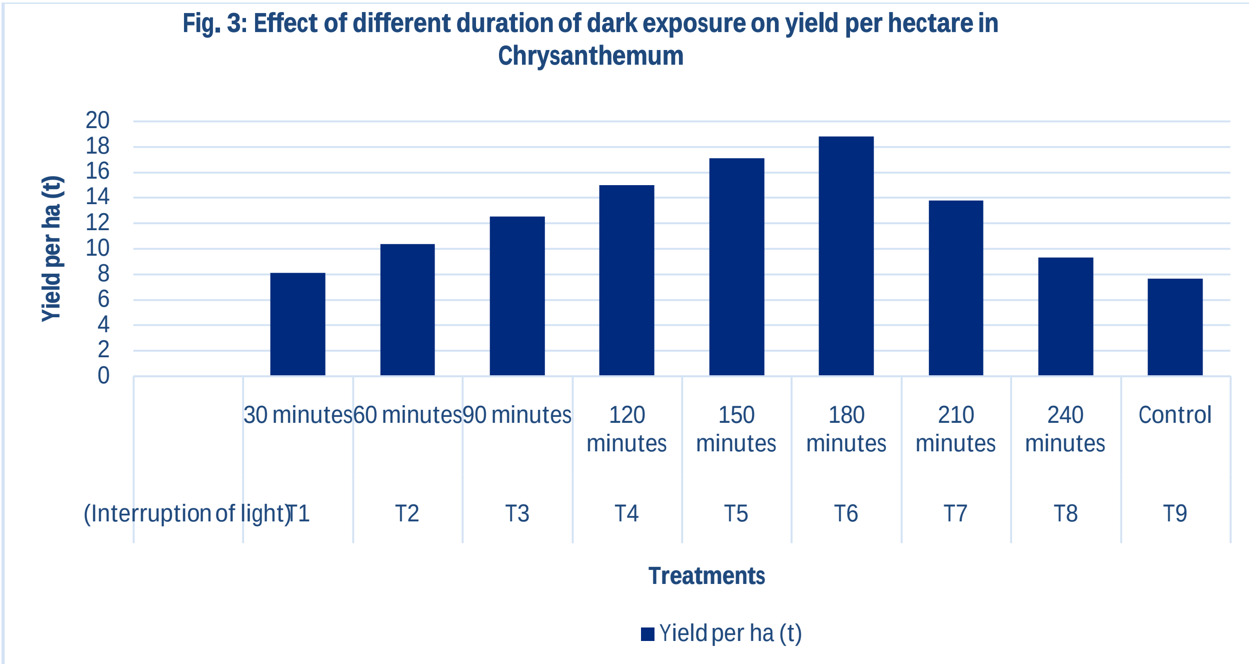
T6 (180 minutes) also showed the highest number of flowers per plant (31.93), whereas T9 (Control) had the least (18.52). Enhanced flowering in T6 aligns with research by Chen et al. (2024), indicating that controlled photoperiods boost floral initiation by modulating key flowering genes. Also, due to 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.

The increased production of flowers observed in this study can be attributed to proper vegetative development and a delay in bud formation due to the midnight (12am to 3am) light interruption. While it is well known that short-day conditions induce flowering in chrysanthemums, the precision light interruption technique used in previous experiment provided a more controlled environment that promoted optimal vegetative growth. The light interruption delayed bud formation, allowing the plants to develop more robust vegetative structures, which subsequently supported a greater number of flowers. Future investigations should focus on understanding the underlying mechanisms, including hormonal changes, gene expression related to flowering, and the impact on photosynthesis and metabolism. Additionally, the influence of other environmental factors such as temperature, humidity, and nutrient availability should be considered. These studies will provide a comprehensive explanation for the enhanced flowering and ensure the robustness of the findings.

Definations

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

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

Disclaimer (Artificial intelligence)

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Details of the AI usage are given below:

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