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ARTIFICIAL LIGHTING FOR SHORTENED CULTIVATION AND HIGHER YIELD IN CHRYSANTHEMUM

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ABSTRACT

In Andhra Pradesh, chrysanthemum cultivation under natural conditions begins in June–July, with flowering occurring from November to January. During this peak season, the heavy influx of flowers into the market results in low farm-gate prices, adversely affecting growers' profitability. To overcome this, a study was conducted at Horticulture Research Station, Anantharajupeta, to shorten the cultivation period and reduce production costs by enhancing vegetative growth through artificial lighting under open field conditions. Chrysanthemum varieties were exposed to supplemental lighting (L_1) using 60 W incandescent bulbs for 5 hours daily (5:30 PM–10:30 PM) for 45 days after planting, while control plants (L_0) were maintained under natural photoperiod. The trial was laid out in a randomized design with 16 treatments (T_1–T_{16}) and three replications. Observations were recorded on growth, flowering, physiological, and yield traits. Results revealed that T_2(V_1L_1– Poornima White with artificial lighting) was the best performer, followed by T_8(V_2L_1– Orange Fair Lady with artificial lighting), whereas T_9(V_5L_0– natural photoperiod) showed the poorest growth and yield. Artificial lighting advanced flowering, reduced crop duration and produced up to a three-fold increase in harvest, demonstrating its potential as a cost-effective strategy for optimizing chrysanthemum production under open field conditions.

Key words : Chrysanthemum, Photoperiod, Artificial light, Incandescent bulbs, Yield.

Introduction

Indian floriculture is predominantly led by crops such as rose, chrysanthemum, marigold, tuberose, orchids and gerbera. Chrysanthemum ranks second only to roses in commercial cut flower production, both in India and globally (Kafi and Ghahsareh, 2009). It is an herbaceous perennial and a qualitative short-day plant with a critical day length of 13.5 hours; long days (>12 h) favour vegetative growth, whereas short days (<12 h) induce flowering. Large-flowered varieties are cultivated for cut flowers and exhibition, while small-flowered varieties are used as loose flowers for garlands, religious offerings, bedding and potting.

Short-day plants require uninterrupted dark periods for flowering, and even brief night light interruptions can delay floral initiation. Night-break treatments using incandescent lamps are employed to manipulate photoperiods, extend vegetative growth and optimize market supply (Hakuzan and Kooriyama, 2013). Several studies have shown that photoperiod manipulation can facilitate off-season chrysanthemum production, enhancing flower quality and farmer profitability (Kazaz *et al*., 2010; Runkle *et al*., 2012; Agata *et al*., 2011).

Materials and Methods

The experiment was conducted at Horticulture Research Station, Dr. Y.S.R. Horticultural University, College of Horticulture, Anantharajupeta, Annamayya district, Andhra Pradesh, during the *Rabi* season of 2024–2025. Eight chrysanthemum varieties were evaluated under two light conditions: L_0– natural photoperiod, and L_1– artificial lighting using 60 W incandescent bulbs.

The study followed a Statistical method of Two-Factorial Randomized Block Design (FRBD) with 16 treatment combinations (T_1–T_{16}) and three replications. Rooted cuttings were planted at 30 × 45 cm spacing. Five plants per treatment were observed at scheduled intervals. Morphological parameters included plant height (cm), number of branches, and stem girth (cm) recorded at 15, 30, 45, and 60 DAP. Physiological parameter included specific leaf weight (g cm^{-2}) at 60 and 120 DAP. Flowering traits recorded were days to flower bud initiation, days to full bloom, number of flowers per plant, and flower yield (kg $plant^{-1}$).

Table 1 : Details of treatment combinations.

T_1	V_1L_0	Poornima white + Without artificial light
T_2	V_1L_1	Poornima white + With artificial light (60 W incandescent bulbs)
T_3	V_2L_0	Poornima yellow + Without artificial light
T_4	V_2L_1	Poornima yellow + With artificial light (60 W incandescent bulbs)
T_5	V_3L_0	Pink Belgium + Without artificial light
T_6	V_3L_1	Pink Belgium + With artificial light (60 W incandescent bulbs)
T_7	V_4L_0	Orange fair lady + Without artificial light
T_8	V_4L_1	Orange fair lady + With artificial light (60 W incandescent bulbs)
T_9	V_5L_0	Ball yellow + Without artificial light
T_{10}	V_5L_1	Ball yellow + With artificial light (60 W incandescent bulbs)
T_{11}	V_6L_0	Star white + Without artificial light
T_{12}	V_6L_1	Star white + With artificial light (60 W incandescent bulbs)
T_{13}	V_7L_0	Mango yellow + Without artificial light
T_{14}	V_7L_1	Mango yellow + With artificial light (60 W incandescent bulbs)
T_{15}	V_8L_0	Aishwarya yellow + Without artificial light
T_{16}	V_8L_1	Aishwarya yellow + With artificial light (60 W incandescent bulbs)

Results and Discussion

Plant height (cm)

Height of the plant was measured with a scale from the base of the plant to the top of the plant at 15, 30, 45 and 60 days after planting (DAP) and expressed in centimeters.

Significant differences in plant height were observed among varieties under artificial lighting from 30 DAP onwards. Maximum height was recorded in V_4L_1– Orange Fair Lady + artificial light, reaching 31.27 cm (30 DAP), 43.40 cm (45 DAP) and 69.00 cm (60 DAP), followed by V_3L_1– Pink Belgium and V_8L_1– Aishwarya Yellow. Minimum height was observed in V_5L_0– Ball Yellow under natural photoperiod represented in Table 2. These findings align with Thakur and Grewal (2016), where night-interruption with incandescent bulbs enhanced stem elongation.

Number of branches

The number of branches emerging from the main

Plate 1 : Day and night view of experimental plot with and without providing artificial light through the incandescent bulbs of 60 W.

Table 2 : Performance of different chrysanthemum varieties as influenced by artificial lighting conditions on plant height (cm) at different stages of crop growth.

Plant height (cm)												
	15 DAP			30 DAP			45 DAP			60 DAP		
	L_0	L_1	Mean	L_0	L_1	Mean	L_0	L_1	Mean	L_0	L_1	Mean
V_1	15.47	16.30	15.88	21.07	21.20	21.13	28.13	40.47	34.30	38.80	53.73	46.27
V_2	14.27	14.27	14.27	19.30	20.77	20.03	28.27	39.00	33.63	41.73	51.30	46.52
V_3	15.97	19.67	17.82	20.07	27.43	23.75	30.00	41.33	35.67	37.80	49.13	43.47
V_4	15.50	20.13	17.82	21.67	31.27	26.47	30.40	43.40	36.90	40.33	69.00	54.67
V_5	12.83	13.80	13.32	19.27	20.40	19.83	25.93	34.27	30.10	37.10	51.87	44.48
V_6	14.80	18.13	16.47	20.33	23.43	21.88	30.67	39.13	34.90	37.60	55.60	46.60
V_7	17.00	13.10	15.05	20.93	20.33	20.63	33.27	34.80	34.03	41.33	50.20	45.77
V_8	13.27	16.83	15.05	20.00	24.80	22.40	31.87	40.07	35.97	37.33	58.60	47.97
Mean	14.88	16.52		20.33	23.70		29.82	39.06		39.00	54.93	
Source	V	L	VxL	V	L	VxL	V	L	VxL	V	L	VxL
SEm±	0.96	0.48	1.35	0.84	0.42	1.19	1.12	0.56	1.58	1.97	0.98	2.78
CD@5%	2.76	1.38	NS	2.42	1.21	3.42	3.22	1.61	4.55	5.68	2.84	8.03

Table 3 : Performance of different chrysanthemum varieties influenced by artificial lighting conditions on number of branches per plant at different stages of crop growth.

Number of branches plant^{-1}												
	15 DAP			30 DAP			45 DAP			60 DAP		
	L_0	L_1	Mean	L_0	L_1	Mean	L_0	L_1	Mean	L_0	L_1	Mean
V_1	1.53	2.07	1.80	6.33	8.33	7.33	6.73	17.47	12.10	11.47	30.00	20.73
V_2	1.40	2.07	1.73	3.07	5.20	4.13	7.13	9.33	8.23	18.60	22.13	20.37
V_3	1.67	1.80	1.73	2.50	6.33	4.42	6.67	12.33	9.50	14.13	21.80	17.97
V_4	1.33	1.73	1.53	3.33	7.33	5.33	8.00	11.67	9.83	11.33	19.00	15.17
V_5	1.40	1.80	1.60	4.13	7.33	5.73	6.93	13.67	10.30	13.47	21.00	17.23
V_6	1.40	1.47	1.43	2.53	6.33	4.43	6.80	13.67	10.23	12.33	18.60	15.47
V_7	1.47	1.73	1.60	4.67	8.00	6.33	7.53	15.67	11.60	12.53	21.67	17.10
V_8	1.40	1.40	1.40	4.00	6.00	5.00	7.53	14.67	11.10	13.93	26.00	19.97
Mean	1.45	1.76		3.82	6.86		7.17	13.56		13.47	22.53	
Source	V	L	VxL	V	L	VxL	V	L	VxL	V	L	VxL
SEm±	0.11	0.05	0.15	0.55	0.28	0.78	0.67	0.34	0.95	1.39	0.70	1.97
CD@5%	NS	0.16	NS	1.60	0.80	NS	1.94	0.97	2.75	4.02	2.01	5.69

stem of the plant was counted in each treatment. The average values were computed and expressed in number plant^{-1}.

Table 3 represents that branching was significant at 45 and 60 DAP. Maximum branching was in V_1L_1– Poornima White (17.47 at 45 DAP, 30.00 at 60 DAP), followed by V_7L_1– Mango Yellow and V_8L_1– Aishwarya Yellow. Minimum branching occurred in V_3L_0 – Pink Belgium and V_4L_0 – Orange Fair Lady. Yang and Jeong (2021) reported that supplemental lighting enhances lateral branching in chrysanthemum.

Leaf area (cm²)

Leaf area was recorded with the help of leaf area meter (HAISERRS-1) with WINDIAS software and their mean values were expressed in cm².

Significant differences in leaf area were observed at 30 and 45 DAP. Highest leaf area was in V_7L_1 – Mango Yellow (35.33 cm² at 30 DAP, 51.71 cm² at 45 DAP), followed by V_2L_1 – Poornima Yellow and V_5L_1 – Ball Yellow. Lowest leaf area was in V_5L_0 – Ball Yellow and V_4L_0 – Orange Fair Lady presented in the Table 4. Artificial lighting promoted leaf expansion, improving photosynthetic capacity (Belay *et al.*, 2021).

Stem girth (cm)

Stem girth was measured just below the first basal node using Vernier calipers multiplied by π at different

Table 4. Impact of artificial light on leaf area (cm^2) of different chrysanthemum varieties at different stages of crop growth.

Leaf area (cm^2)												
	15 DAP			30 DAP			45 DAP			60 DAP		
	L_0	L_1	Mean	L_0	L_1	Mean	L_0	L_1	Mean	L_0	L_1	Mean
V_1	13.43	13.34	13.38	19.49	27.86	23.67	30.39	38.74	34.57	35.00	51.01	43.01
V_2	12.05	12.38	12.21	22.20	32.85	27.53	30.29	46.25	38.27	35.18	50.40	42.79
V_3	12.82	15.08	13.95	18.00	24.77	21.39	32.33	48.10	40.22	40.00	49.18	44.59
V_4	12.10	16.38	14.24	19.00	24.67	21.83	26.98	41.42	34.20	30.34	47.60	38.97
V_5	10.76	15.68	13.52	15.67	25.49	20.58	24.40	50.00	37.20	34.43	55.07	44.75
V_6	11.90	14.61	13.25	22.67	24.05	23.36	27.44	45.24	36.34	35.00	53.26	44.13
V_7	10.97	16.41	13.69	19.33	35.33	27.33	30.70	51.71	41.20	41.67	60.51	51.09
V_8	11.74	12.45	12.10	17.33	21.80	19.57	25.48	44.51	35.00	34.14	53.93	44.03
Mean	12.04	14.54		19.21	27.10		28.50	45.75		35.72	52.62	
Source	V	L	VxL	V	L	VxL	V	L	VxL	V	L	VxL
SEm±	1.06	0.53	1.50	0.99	0.50	1.41	1.65	0.82	2.33	2.09	1.05	2.96
CD@5%	NS	1.53	NS	2.87	1.44	4.06	4.75	2.38	6.72	6.04	3.02	NS

Table 5 : Impact of artificial light on stem girth (cm) of different chrysanthemum varieties at different stages of crop growth.

Stem girth (cm)												
	15 DAP			30 DAP			45 DAP			60 DAP		
	L_0	L_1	Mean	L_0	L_1	Mean	L_0	L_1	Mean	L_0	L_1	Mean
V_1	0.21	0.25	0.23	0.27	0.35	0.31	0.53	0.83	0.68	0.69	0.94	0.82
V_2	0.19	0.27	0.23	0.28	0.35	0.31	0.56	0.83	0.70	0.71	0.92	0.82
V_3	0.17	0.29	0.23	0.25	0.35	0.30	0.48	0.59	0.53	0.68	0.65	0.66
V_4	0.20	0.32	0.26	0.27	0.42	0.35	0.58	0.85	0.72	0.72	1.16	0.94
V_5	0.20	0.28	0.24	0.26	0.37	0.32	0.61	0.76	0.69	0.79	0.85	0.82
V_6	0.20	0.27	0.23	0.27	0.34	0.31	0.55	0.72	0.64	0.74	0.78	0.76
V_7	0.19	0.26	0.22	0.31	0.33	0.32	0.58	0.66	0.62	0.73	0.74	0.74
V_8	0.22	0.28	0.25	0.31	0.34	0.33	0.66	0.74	0.70	0.77	0.83	0.80
Mean	0.20	0.28		0.28	0.36		0.57	0.75		0.73	0.86	
Source	V	L	VxL	V	L	VxL	V	L	VxL	V	L	VxL
SEm±	0.01	0.01	0.02	0.03	0.01	0.04	0.03	0.02	0.04	0.04	0.02	0.05
CD@5%	NS	0.02	NS	NS	0.04	NS	0.09	0.04	NS	0.10	0.05	0.15

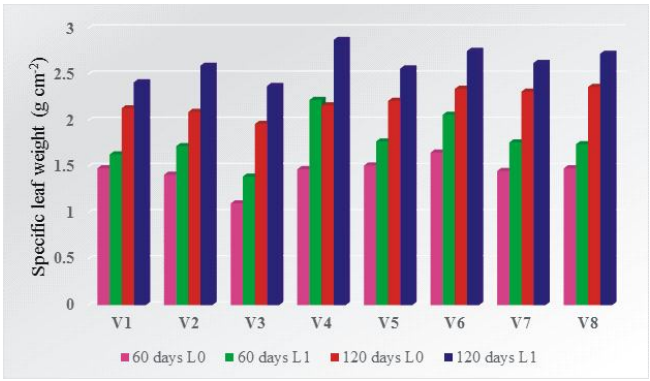

Fig. 1 : Specific leaf weight in different chrysanthemum varieties grown under natural photoperiod and exposed with extended day length by artificial lighting conditions.

stages of plant growth. The average values were worked out and expressed in centimeters

Stem girth differed significantly only at 60 DAP. Maximum girth was recorded in V_4L_1 – Orange Fair Lady (1.16 cm), followed by V_1L_1 – Poornima White (0.94 cm), whereas minimum girth was in V_3L_0 – Pink Belgium (0.68 cm) showed in the Table 5.

Specific Leaf weight (g cm^{-2})

Specific leaf weight was measured from five randomly selected plants, fully expanded third leaf (from main stem apex) was collected. Leaflets were separated, petioles were discarded and area was measured with leaf area meter. Then the Leaflets were dried in hot air oven at 60^0 for about 48 hours and the dry weight was taken

Table 6 : Impact of artificial light on specific leaf weight (g cm^{-2}) of different chrysanthemum varieties at 60 and 120 days after planting.

Specific leaf weight (g cm^{-2})						
	30 DAP			60 DAP		
	L_0	L_1	Mean	L_0	L_1	Mean
V_1	1.48	1.63	1.56	2.13	2.41	2.27
V_2	1.41	1.72	1.56	2.09	2.59	2.34
V_3	1.10	1.39	1.25	1.96	2.37	2.17
V_4	1.47	2.22	1.84	2.16	2.87	2.52
V_5	1.51	1.77	1.64	2.21	2.56	2.39
V_6	1.65	2.06	1.85	2.34	2.75	2.54
V_7	1.45	1.76	1.61	2.31	2.62	2.47
V_8	1.48	1.74	1.61	2.36	2.72	2.54
Mean	1.44	1.79		2.20	2.61	
Source	V	L	VxL	V	L	VxL
SEm±	0.07	0.04	0.10	0.08	0.04	0.12
CD@5%	0.21	0.11	NS	0.24	0.12	0.35

Table 7 : Impact of artificial light on number of days taken for first flower bud initiation, flowering and number of days to full blooming and flower yield in different chrysanthemum varieties.

	Flower yield (kg $plant^{-1}$)		
	L_0	L_1	Mean
V_1	0.30	1.80	1.05
V_2	0.23	1.32	0.77
V_3	0.14	0.88	0.51
V_4	0.36	1.56	0.96
V_5	0.19	0.72	0.46
V_6	0.11	0.72	0.41
V_7	0.22	0.56	0.65
V_8	0.17	1.00	0.59
Mean	0.28	1.07	
Source	V	L	VxL
SEm±	0.05	0.02	0.08
CD@5%	0.16	0.08	0.23

with the help of electronic balance. SLW was calculated using

$$\text{SLW (g cm}^{-2}) = \frac{\text{Dry weight}}{\text{Leaf area}}$$

At 120 DAP, V_4L_1 – Orange Fair Lady recorded the highest specific leaf weight (2.87 g cm^{-2}), followed by V_6L_1 – Star White. Minimum was in V_3L_0 – Pink Belgium (1.96 g cm^{-2}) represented in Table 6.

Flowering parameters

Minimum days to flower bud initiation occurred in V_4L_0 – Orange Fair Lady (37.00), while maximum was in V_1L_1 – Poornima White (85.00), followed by V_2L_1 – Poornima Yellow (79.00). Similarly, days to full blooming were shortest in V_4L_0 (78.33) and longest in V_1L_1 - (120.33), followed by V_7L_1 – Mango Yellow (114.33).

Flower Yield (kg $plant^{-1}$)

The methodology of flower weight is at each harvest, the number of fresh flowers harvested was weighed and the mean was expressed as flower yield per plant in kgs.

Highest yield was in V_1L_1 – Poornima White (1.80 kg), comparable to V_4L_1 – Orange Fair Lady (1.55 kg), while the lowest yield was in V_6L_0 – Star White (0.11 kg). These results support Kumar *et al.* (2017), who found that extended day length using artificial lighting enhances flower development and yield.

Conclusion

Supplemental artificial lighting (60 W incandescent bulbs) significantly improved growth, flowering, and yield in chrysanthemum under open-field conditions. Varieties under extended photoperiod (L_1) outperformed those under natural light (L_0), emphasizing the importance of photoperiod manipulation. T_2 – V_1L_1 (Poornima White + artificial light) was the top performer, followed by T_8– V_4L_1 (Orange Fair Lady + artificial light). In contrast, T_9 – V_5L_0 (Ball Yellow under natural light) showed the poorest performance, highlighting the role of artificial lighting in optimizing chrysanthemum production.

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