

Original Research Article

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Effect of Photosynthetically Active Radiation (PAR) from LEDs on Growth and Development of *Chrysanthemum morifolium* Ramat. cv. Zembla

Sunil Kumar^{1*}, M.C. Singh¹, Subedar Yadav¹ and D.K. Sharma²

¹Division of Floriculture and Landscape Architecture, IARI, New Delhi -110012, India

²Centre for Environment Science and Climate Resilient Agriculture, IARI,
New Delhi -110012, India

*Corresponding author

ABSTRACT

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The experiment was conducted to study the effect of photosynthetically active radiation (PAR) on growth and development of chrysanthemum using LEDs. The chrysanthemum cv. Zembla were exposed to different photoperiodic treatments of day length extension illuminating from photosynthetically active radiation from LEDs for 6, 9, 12, 15 days at 15h/day in growth chamber except for control. Every batch after exposure at 6, 9, 12, 15 days under red/blue LEDs was transferred to the chamber with white LEDs. All the growth and physiological parameters (plant height, number of leaves, internode length, leaf chlorophyll, leaf area and net photosynthetic rate) differed significantly during different stages of growth and found that the increased in photoperiod by 15 days with long days from LEDs there was an increase in plant height (43.05cm), inter nodal length (2.60cm), number of leaves (24.50) and leaf area (224.83 cm²) cv. Zembla maximum (15 days) exposure in LEDs. Early flower response was noticed which was advanced by 7 days as compared with control. Bud and flower diameter (5.78 mm and 80.74 mm) were maximum. Fresh and dry weight in stems and flower were significant which might have contributed with increased total chlorophyll (4.43 mg g⁻¹ fw) content as application of light emitting diodes (LEDs) might be resulted in long day effect without disturbing the required minimum dark period for flower induction.

Introduction

Chrysanthemum is the most important cut flower in India as well as globe. It is qualitative short day plants (SDP), hence, flower induction is primarily regulated by light duration (photoperiod). It flowers uniformly when critical day-length photoperiod is ≈ 13.5 h or less, but fails to flower under the longer critical photoperiods (McMahon, 1999). At northern latitudes, chrysanthemums are grown in greenhouses year-round. In terms of floriculture,

photoperiod control should focus on minimizing the number of days to flower induction. In cut chrysanthemum production, artificially long days (LDs) are maintained routinely for 2–3 weeks before the onset of short day (SD), because of the required stem length specification (Hisamatsu *et al.*, 2008). The importance of light quality for morphogenesis has been reported in many plant species. Plants sense light quality via photoreceptors categorized as phytochromes,

cryptochromes and phototropins, and these photoreceptors are in charge of a wide spectrum of morphogenesis (Takemiya *et al.*, 2005). Among them, phytochromes are red and far-red light-sensitive but cryptochromes and phototropins absorb blue (B) light (Lin, 2000). Extended stem length has been shown to occur as a part of a phytochrome-mediated response (Patil *et al.*, 2003). In contrast to phytochromes, 'B' light related-photoreceptors have also been suggested to be involved in the flowering process (Fankhauser and Ulm, 2011). It has been previously reported that supplemental 'B' light induces the flowering response of chrysanthemum more than critical day-length (Jeong *et al.*, 2012). Thus, it is likely that supplemental B lighting has important functions in the flowering process. The application of supplemental lighting also allows greenhouse crops to promote biomass accumulation by increasing photosynthetic carbon assimilation (Hao and Papadopoulos, 1999). Therefore, using a B light supplementation may be a useful practical technique for optimizing cut chrysanthemum cultivation. However, there is limited literature on the effects of supplemental B light on the stem elongation of cut chrysanthemum. Furthermore, since the effect of B light in relation to photoperiod length remains unknown, more knowledge is required about this phenomenon. So, keeping above view in mind an experiment was carried out to analyze the influence of photosynthetically active radiation (PAR) on growth and development of chrysanthemum using light-emitting diodes (LEDs).

Materials and Methods

A cultivar "Zembla" was used in this experiment. Terminal cuttings of 5-6 cm length were taken from the mother plants of cv. Zembla and propagated as self-rooted plants in a plug (pro)- tray filled with soil less media (a mixture of coco-peat, vermiculite

and perlite in a ratio 3:1:1). After 30 days attaining 5-7 leaves and transplanted in a 10 cm diameter (and 7.3 cm depth), UV stabilized plastic pot filled with a growing media composed of well-prepared mix of soil, vermi-compost, sand and organic leaf manure. 20 uniform sized plants were selected, transplanted, fertigated with 2g/l mixture of 19:19:19 NPK and Then kept for healing under greenhouse conditions with long days before being exposed to lighting treatments. The experiment was conducted based on completely randomized design (CRD).

The plants healed for 15 days were placed in the growth chamber for the experiment on chrysanthemum was carried out during February, 2015 to May, 2015 in a growth chamber in field laboratory of CPCT, IARI at New Delhi. Whereas, the light intensity was fixed by making two different LED panels, one white LEDs and in another a mixture of red and blue LEDs. To achieve an interception of light at 110-120 $\mu\text{mol m}^{-2} \text{sec}^{-1}$ from 80% red 20% blue PAR distributed over the plants in uniformity inside the growth chamber. LEDs light exposure was given for 15 hours as long day (LD) treatment except for control. Every batch after exposure at 6, 9, 12, 15 days under red/blue LEDs was transferred to the chamber with white LEDs. The light intensity was measured every day and plants were re-positioned for an optimal irradiance available. Each growth chamber had constant lighting for 15h as long day for entire 15 day period. After the completion of the all treatments, plants that were exposed shifted to the greenhouse, maintained with day temperature, 24°C and night temperature fixed at 16-18°C.

Observations were recorded on plant height (cm), stem diameter (mm), total number of leaves, leaf area (cm^2), leaf fresh and dry weight, stem fresh and dry weight (electronic wastage and hot air oven), net photosynthetic

rate, stomatal conductance and total chlorophyll were measured at 0, 15, 30 and 45 days after planting and time taken for flower bud induction, bud diameter (mm), time taken for flower opening (day) and flower diameter (mm), flower fresh and dry weight were taken at blooming time. Photosynthetic rate and stomatal conductance rate were measured (4th leaf from the apical terminal) using an infrared gas analyzer (LI-COR, Biosciences, USA, Model LI 64000). The CO₂ concentration of the air entering the leaf chamber was adjusted to 400 mmol⁻¹ by using a CO₂ gas container, and leaf temperature was maintained at 22^oC. Total leaf area was measured by using leaf area meter, LI-COR (Model 3100). Chlorophyll content in the leaves was measured by DMSO method (Hiscox and Israelstam, 1979). The data were analyzed by using statistical package OPSTAT version.

Results and Discussion

The effect of long days through LEDs was pronounced on plant height and recorded maximum (43.05cm) in the plants kept for 15 days measured at 45 days after planting. Whereas, plants kept under control (Long day exposure with white LEDs) could attain only 31.5 cm registered 36.66 % increase due to longest (15 days) exposure under LEDs. However, the effect of different photoperiods from LEDs was significant and improved the stem thickness. Maximum stem diameter (5.16 mm) was recorded at 45 day after transplanting under 15 days exposure. However, an increase of 10.49 % in stem diameter was estimated due to 15 day exposure over the control. Stem diameter increased with the plant growth and subsequently resulted in higher accumulation of dry matter in the plants. This is, because of more cell elongation, and increased internodal length and plant height. Since, chrysanthemum is an obligate short day plant,

internal genetic behaviour of the plant hastens flowering without sufficient vegetative growth of plant in the absence of sufficient light. An experiment, application of different photoperiodic lengths on short day planted chrysanthemum has little influence of stem diameter as supported by the results achieved by Li *et al.*, (2010) that the leaf attained more thickness under blue light in comparison with red light and different mixture of red and blue light in upland cotton. Kim *et al.*, (2004) also found that different synergistic interaction between blue and red light receptors promote the stem elongation but its depending upon the nature of species.

The longest internodal length was measured at 45th days after planting in the plants exposed with LEDs for 15 days (2.60 cm). However, the shortest internodes were recorded in the plants kept under control (2.05 cm). Increase in plant height and stem elongation was resulted due to increase in length of internodes rather than number of internodes. Similar findings were reported by Appelgren (1991) found significant differences recorded in internodes length but non-significant in internode number due to the effect of light quality. Similarly Kim *et al.*, (2004) also reported that stem elongation in chrysanthemum was due to internodes length rather than their number and no effect of light quality in number of internodes was observed.

Maximum number of leaves (24.50) was recorded at 15 day exposure of LEDs followed by 12 days (23.50) and remains significantly higher than the recorded in the plants grown under control (19.75). On the other, maximum leaf area (224.83 cm²) was exhibited in the leaves of the plants exposed with long day LEDs for 15 day estimated 45 day after transplanting. However, plants without illumination with LEDs (control) had a lowest value (196.18 cm²). This might be

due to enhanced biosynthesis of protein and carbohydrates leading to enhancement of initiation of leaf primordial growth under the influence of extended photoperiod and consequently production of more leaves. With the application of light treatment, the leaf area might have increased due to induced cell expansion as reported by Kim *et al.*, (2004) that the leaf area was also greatest under FL and RB, while decreased mostly under BFr. Macedo *et al.*, (2011) also found that the number of leaves/plant in *Alternanthera brasiliana* were significantly increased under blue fluorescent light as compared to with the other fluorescent- light and dark treatment.

The maximum leaves fresh weight was gained at 15 day (8.64g) light treatment followed by 12 (8.35g) and 9 days (8.12g) days exposure and remained significant as compared with control (6.43g). The dry weight of the leaves showed the similar trend for the treated plants and accumulated a highest dry weight (1.34g) in the plants exposed for 15 days exposure with LEDs followed by plants under 12 days (1.23g) harvested at 45 days as compared to the plants kept under the control (0.90 g). The maximum gain in fresh weight of stem (7.81 g) in the plants treated with 15 days period as compared to the minimum (5.25g) in the plants under control. Maximum dry weight accumulated in stems (1.55g) in the plants exposed with 15 days as compared to lowest (1.10 g) in control. The increase in leaf weight of plants treated with light was due to the increase in leaf number as well as leaf size whereby more dry matter accumulated from the increased levels of photosynthetic pigment like chlorophyll and carotenoid. The findings of Menard *et al.*, (2006), support this fact that the supplemental blue light increased plant dry weight of cucumber and tomato. Similarly Kim *et al.*, (2004) found that the fresh weight, dry weight were also greatest under FL and RB, while decreased the most under BFr. The data revealed that a maximum bud (5.78 mm)

and flower diameter (80.74 mm) were recorded in 15 days long day exposed plants as compared to the minimum (4.71 mm and 75.2 mm, respectively) under control. It is evident from the data that an increase in day length exposure beyond 6 days to 15 days from LEDs, there was 22.71 % increase in bud size over the diameter recorded in the treated plants over control. The flower harvested from the plants treated with long day LEDs exposure given for 6, 9 and 12 days was recorded 76.54 mm, 78.31 mm and 79.06 mm, respectively which remained were at par with flower size attained at 15 days exposure to LEDs lighting (Table 1).

Flower bud initiation periods, however varied from 54 days in the plants exposed with longest duration (15 days) and had earliest appearance of flower bud as compared with control plants (61 days) which was delayed by 7 days. The plants treated with long day LED exposure for 6, 9 and 12 days had shown a significant early in flower bud induction by 1, 4 and 6 days over the control. Time taken for flower opening varied significantly among the treated plants with long day exposure through LEDs as presented in table 2 and revealed that flower opening took maximum time was under control (70.75 days) followed by plants exposed for 6 days (70.50) and remained at par with each other. Whereas, 15 days long LEDs exposure could resulted in earliest (65.75 days) flower opening. Day length, if extended under natural available short day (SD) period, promotes vegetative growth and delays flowering. Bagnall *et al.*, (1996) found that absorption of blue light accelerates flowering in *Arabidopsis* and *Hyacyanus*. Higuchi *et al.*, (2012) reported that blue light plays an important role in the promotion of flowering under long day condition. Highest fresh and dry weights of flowers harvested from 15 days treated plants (5.78g and 0.79g, respectively).

Table.1 Effect of photosynthetic active radiation (PAR) from LEDs on plant height, stem diameter, internodal length, number of leaves per stem and leaf area in *Chrysanthemum morifolium* cv. Zembla

Treatment	Plant height (cm)				Stem diameter (mm)				Internodal length (cm)				Number of leaves/plant				Leaf area (cm ²)			
	Day after planting				Day after planting				Day after planting				Day after planting				Day after planting			
	0	15	30	45	0	15	30	45	0	15	30	45	0	15	30	45	0	15	30	45
0 day (control)	11.05	15.10	22.12	31.50	3.65	3.67	4.18	4.67	1.28	1.40	1.58	2.05	11.00	15.25	17.50	19.75	103.92	149.70	174.45	196.18
6 days	11.05	15.50	23.12	33.57	3.49	3.89	4.17	4.86	1.35	1.48	1.70	2.13	10.75	16.00	18.25	20.50	105.19	154.73	180.08	201.35
9 days	11.05	17.00	25.95	36.60	3.66	3.96	4.44	4.89	1.28	1.55	1.63	2.15	10.25	17.25	19.25	20.25	101.17	162.85	184.30	205.15
12 days	11.05	17.57	27.37	42.02	3.74	4.09	4.55	5.13	1.33	1.60	1.83	2.38	10.75	17.25	19.50	23.50	100.97	168.10	188.90	216.78
15 days	11.07	19.00	28.8	43.05	3.63	4.14	5.01	5.16	1.40	1.85	2.05	2.60	11.00	18.00	20.00	24.50	100.15	176.08	197.35	224.83
C.D 0.05	NS	1.67	2.32	3.77	NS	0.24	0.24	0.24	NS	0.18	0.23	0.25	NS	1.37	1.64	1.86	NS	9.16	10.68	9.16
SE(m)±	0.29	0.55	0.76	1.24	0.13	0.07	0.08	0.08	0.06	0.06	0.07	0.08	0.41	0.45	0.54	0.61	1.81	3.01	3.51	3.01

Table.2 Effect of photosynthetic active radiation (PAR) from LEDs on Leaves fresh, dry weight, stem fresh, dry weight, bud diameter, flower diameter, time taken for flower bud induction, flower opening, flower fresh and dry weight in *Chrysanthemum morifolium* cv. Zembla

Treatment	Leaves fresh weight(g)				Leaves dry weight(g)				Stem fresh weight(g)				Stem dry weight(g)				Bud diameter (mm)	Flower diameter (mm)	Time taken for flower bud induction (day)	Time taken for flower opening (day)	Flower fresh weight(g)	Flower dry weight
	Day after planting				Day after planting				Day after planting				Day after planting									
	0	15	30	45	0	15	30	45	0	15	30	45	0	15	30	45						
0 day (control)	3.61	4.22	4.68	6.43	0.39	0.62	0.71	0.90	1.56	3.29	3.86	5.25	0.26	0.58	0.80	1.10	4.71	75.20	61.25	70.75	4.71	0.61
6 days	3.66	6.06	6.79	7.36	0.42	0.79	0.99	1.06	1.71	3.36	4.21	5.95	0.29	0.62	0.84	1.24	4.81	76.54	60.50	70.50	4.81	0.60
9 days	3.73	6.05	7.33	8.12	0.41	0.80	1.07	1.24	1.77	3.44	4.36	6.18	0.28	0.64	0.89	1.27	5.06	78.31	57.75	68.50	5.06	0.70
12 days	3.63	6.26	7.32	8.35	0.40	0.83	1.08	1.23	1.60	3.49	5.52	6.61	0.26	0.64	1.12	1.34	5.62	79.06	55.75	67.00	5.62	0.79
15 days	3.61	6.77	7.83	8.64	0.38	0.87	1.27	1.34	1.60	3.54	5.95	7.81	0.29	0.67	1.21	1.55	5.78	80.74	54.00	65.75	5.78	0.79
C.D 0.05	NS	0.64	0.92	0.56	NS	0.06	0.19	0.11	NS	NS	0.68	0.52	NS	NS	0.14	0.10	0.24	2.11	1.32	0.92	0.24	0.05
SE(m)±	0.13	0.21	0.30	0.18	0.02	0.02	0.06	0.04	0.12	0.08	0.22	0.17	0.02	0.03	0.05	0.03	0.08	0.70	0.43	0.30	0.08	0.02

Fig.1 Effect of photosynthetic active radiation (PAR) from LEDs on net photosynthetic rate in *Chrysanthemum morifolium* cv. Zembla

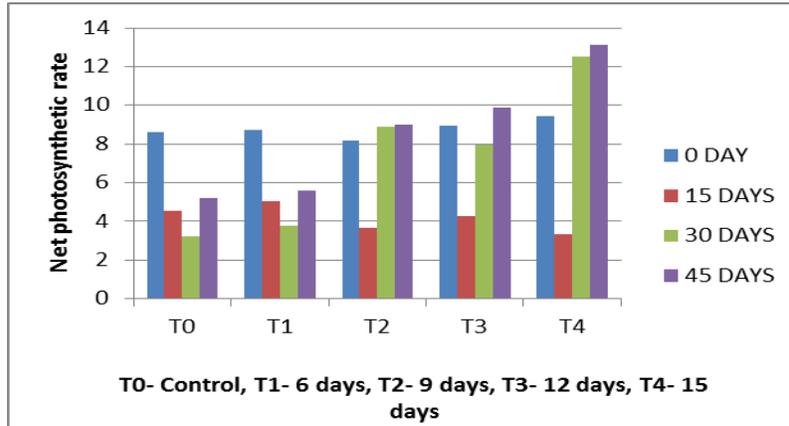


Fig.2 Effect of photosynthetic active radiation (PAR) from LEDs on stomatal conductance in *Chrysanthemum morifolium* cv. Zembla

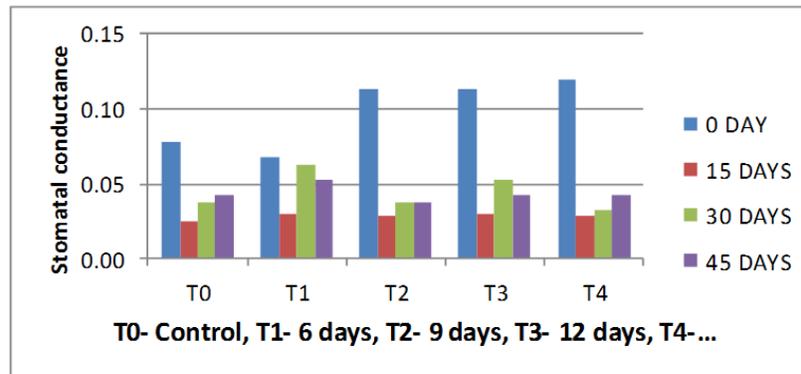
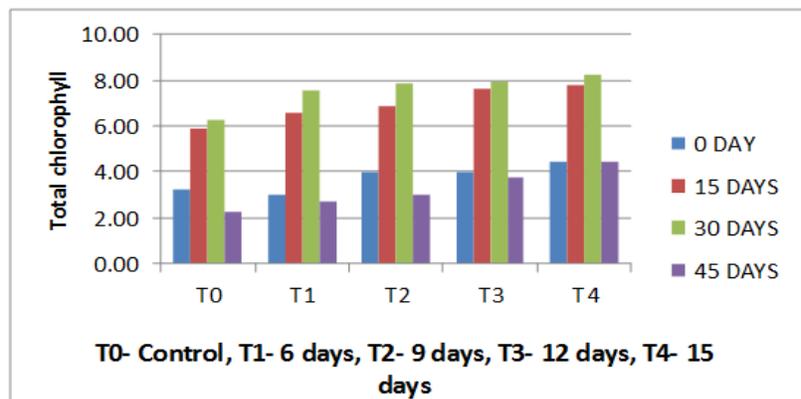


Fig.3 Effect of photosynthetic active radiation (PAR) from LEDs on total chlorophyll in *Chrysanthemum morifolium* cv. Zembla



However the fresh weight differences were less pronounced in flowers from plants exposed under all four different length of exposures from LEDs. Dry weight of the flowers also showed an increased with increase in exposure duration and registered an increase 29.50 % in the dry weight accumulated at 15 days long LEDs exposure as compared with flowers harvested from the plants under control (0.61g).

The photosynthetic activity (Fig. 1) was found significantly higher in the leaves of plants kept under 15 days ($13.14 \mu\text{molm}^{-2}\text{s}^{-1}$) long day effect of LEDs measured 45 days after planting followed by the plants kept under 12 days long day treatment ($9.90 \mu\text{molm}^{-2}\text{s}^{-1}$) as compared with lowest in the plants under control ($5.23 \mu\text{molm}^{-2}\text{s}^{-1}$). Stomatal conductance was recorded (Fig. 2) and showed a non-significant difference among the plants with and without long day exposure except for the plants provided with LEDs for 15 days and measured at 15 ($0.05 \mu\text{molm}^{-2}\text{s}^{-1}$) and 30 (0.06) days after planting. Light quantity and quality has a profound effect on growth and flowering in chrysanthemum. Runkle and Heins (2006) were observed that plant receive more light so that the increase higher photosynthetic activity in plants. Kim *et al.*, (2004) revealed that the net photosynthetic rate was highest under RB light followed by FL and lowest under BFr and B. Treated plants had more chlorophyll ($4.43 \text{ mg g}^{-1} \text{ fw}$) measured in leaves exposed for 15 day long day exposure as compared with the leaves of untreated plants (control) and had a chlorophyll content of $2.22 \text{ mg g}^{-1} \text{ fw}$ (Fig. 3). Whereas, plants grown under other exposures lengths of LEDs had increased values ranging from $3.04 \text{ mg g}^{-1} \text{ fw}$ at 9 days to $3.74 \text{ mg g}^{-1} \text{ fw}$ at 12 days long exposure with LEDs. Blue light is very much important for chlorophyll formation, enzyme synthesis and photomorphogenesis as well (Menard *et al.*, 2006). Whereas, Shin *et al.*, (2008) reported that chlorophyll content was found to be highest in the plant grown under mixed blue plus red LEDs, followed by blue LEDs and florescent treatment and the red LEDs treatment showed remarkable reduction in chlorophyll content.

In conclusion, long days with 80% red 20% blue PAR from LEDs were found significant for plant height, inter nodal length, number of leaves and leaf area cv. Zembla at 15 days exposed in LEDs. Early flower response was noticed which was advanced by 7 days as compared with control. Bud and flower diameter were maximum. Fresh and dry weight in stems and flower were significant which might have contributed with increased total chlorophyll content as application of light emitting diodes (LEDs) might resulted in long day effect without disturbing the required minimum dark period for flower induction. The results of this study present a useful practical technique for cut chrysanthemum production in greenhouse horticulture.

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