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EFFECTS OF DIFFERENT SOURCES OF LIGHT AS NIGHT BREAK ON GROWTH CHARACTERISTICS OF KOREAN CHRYSANTHEMUM (*CHRYSANTHEMUM MORIFOLIUM* RAMAT.) GENOTYPES

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Abstract

Longer photoperiods in the form of night break (NB) were applied in chrysanthemum to inhibit the flower bud differentiation for regulating the production and supply in the market. The present study reports the effect of three sources of light (Incandescent bulbs, compact fluorescent lights (CFL) and light emitting diodes-LED) as NB treatment on ten genotypes of Korean chrysanthemum for two years i.e. 2015 and 2016. The NB treatment with LED lights resulted in increased internodal length (8.20 and 9.00 mm), partitioning coefficient (30.50 and 31.50), number of stomata per unit area (56.08 and 56.87), anthocyanins (8.99 and 9.16 mg/g) and carotenoids (28.11 and 28.39 mg/g). However, leaf thickness, petiole length, leaf area index, and leaf weight ratio were affected non-significantly. But petiole girth was recorded maximum (1.22 and 1.49 mm) under incandescent bulbs which was at par with LED and significantly higher than CFL.

Introduction

Korean chrysanthemum (*Chrysanthemum morifolium* Ramat.) belonging to family Asteraceae is the commercial flower which is grown for cut flowers, loose flowers, pot mum as well as bedding plant. Singh and Bala (2018) and Thakur and Grewal (2019) have demonstrated the benefits of using supplementary light during the winter periods to raise the levels of visible radiation for the production of cut flowers and pot plants. Chrysanthemum being a short-day plant requires less than 13½ hrs of photoperiods for the development of flower buds (Kofranek 1992). The photoperiods in chrysanthemum may be increased by giving night break (NB) treatment which is widely used in production of chrysanthemum by applying incandescent lamps to inhibit flowering thereby forcing the plant to remain in vegetative phase. For NB treatment various sources of light like high pressure sodium lamp, incandescent bulbs, fluorescent tube lights etc. are being used in horticulture for photoperiodic control as well as for production purpose. New sources of light for photoperiodic manipulations for horticultural applications, intending to replace high pressure sodium lamps or fluorescent tubes are currently being introduced in the market. Special attention is being devoted to light emitting diodes (LED) technology, which are generally assumed to be more efficient for driving photosynthesis to optimum range (Bergstrand and Schussler 2012). As solid-state devices, they are more robust than traditional lamps with fragile filaments, electrodes, or gas-filled, pressurized lamp enclosures. Since LEDs can be manufactured to be wavelength selectable, absorption peaks of plant pigments or action spectra of leaves can be matched by narrow-spectrum LED emitters, thereby maximizing quantum efficiencies and energy savings (Massa *et al.* 2006). Morrow (2008) also highlighted the advantages of LED lighting including the ability to control spectral quality for improving photosynthetic efficiency, the ability to produce high light levels with low radiant heat, and operating capabilities that are helpful to reduce power use. Therefore, keeping this in view the effect of different sources of light on physiological attributes which directly or indirectly contribute to flower production, the present

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study was undertaken to compare the effect of conventional sources of light for NB treatment in Korean chrysanthemum.

Materials and Methods

The experiments were carried out at Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana during 2015 and 2016. Ten genotypes of chrysanthemum belonging to Korean type, namely Banglori Local, Boris Becker, Reagan White, Kelvin Mandarin, NBRI Sunil, Reagan Emperor, Otome Pink, Jaya, Punjab Shyamli and Yellow Delight, were raised through the rooting of terminal cuttings during end of June to mid-July. The rooted cuttings were transplanted in the pots of 20 cm diameter containing mixture of garden soil and well rotten Farm Yard manure (2 : 1) along with diammonium phosphate @1kg per cubic feet. The pots were placed under longer photoperiodic conditions created as NB, from 15th August to 31st October, as day length starts receding less than 14 hrs after 15th August. The NB treatment was provided by using three sources of light *viz.*, incandescent bulbs, CFL and LED lamps of approximately same wattage (25 W) for two hrs from 10.00 p.m. to 12.00 midnight daily. The plants were shifted to natural day length on 1st November. The varieties were subjected to pinching as per the standard practice. The observations were recorded on vegetative and at the time of flowering.

Partitioning coefficient: PC was calculated at commercial harvesting stage, as follows:

$$\frac{\text{Dry weight of flowers}}{\text{Dry weight of plants}} \times 100$$

Leaf area index (LAI) (Gardener *et al.* 2003) LAI was calculated as follows:

$$\text{LAI} = \frac{\text{Total leaf area per plant} \times \text{number of plants/m}^2}{\text{Surface area of land}}$$

Leaf weight ratio: LWR was calculated as follows:

LWR = Dry weight of leaves/ dry weight of plant.

To calculate number of stomata per unit area, Olympus trinocular microscope with a magnification of 100X was used. Numbers of stomata were counted on three randomly chosen areas on the leaf surface (1 mm^2, middle of leaf on both sides of the main vein) on abaxial and adaxial surfaces of the leaves.

Experiment was laid out with three replications consisting five pots each, in completely randomized design. Statistical analysis was performed using SAS software and the means were compared using DMRT at 5% level of significance.

Results and Discussion

The plants under LED light exhibited highest internodal length during 2015 and 2016 (8.20 and 9.00 mm, respectively). However, the lowest internodal length was recorded in CFL for the both years (7.70 and 7.89 mm, respectively) which was at par with incandescent bulb (Table 1). Among the genotypes, on averaging across the different light sources, significantly the highest internodal length (10.83 and 11.02 mm) was observed in genotype Punjab Shyamli during 2015 and 2016, respectively. Whereas, the minimum internodal length was observed in genotype Banglori Local (4.53 mm 4.74 mm) during the same period of study. The increased internodal length contribute to enhanced flower stem length which is a useful quality parameter for fetching higher price for the cut flowers. Sarkka *et al*. 2017 have also found the incremental increase in internodal length and water use efficiency while comparing the effects of LED and high-pressure sodium (HPS) on cucumber plant morphology and yield but the results obtained, are however, in contradiction with those as reported by Kumar and Singh (2017), who have reported non-significant effect of extended photoperiods on internodal length in chrysanthemum cultivar Zembla using HPS lamps. Further leaf thickness, petiole length, leaf area index and leaf weight ratio were not significantly affected by the sources of the light applied but the average across all

Table 1. Effect of different sources of light as night break on internodal length in Korean chrysanthemum.

Sl. No.	Genotype	Internodal length (mm)							
		2015			Mean	2016			Mean
		Incandescent bulb	CFL	LED		Incandescent bulb	CFL	LED	
1	Banglori Local	2.67	1.81	9.11	4.53[e]	2.84	2.03	9.35	4.74[c]
2	Boris Becker	7.41	8.10	7.95	7.82[c]	7.61	8.30	8.19	8.03[ab]
3	Reagan White	7.36	6.67	8.51	7.51[c]	7.61	6.92	8.78	7.77[b]
4	Kelvin Mandarin	5.37	6.00	9.69	7.02[cd]	5.55	6.18	9.92	7.22[bc]
5	NBRI Sunil	8.56	8.83	1.10	6.16[d]	8.73	9.00	7.10	8.28[ab]
6	Reagan Emperor	10.75	9.55	7.62	9.31[b]	10.91	9.72	7.80	9.48[ab]
7	Otome Pink	7.77	6.63	8.83	7.74[c]	8.19	6.78	8.99	7.99[ab]
8	Jaya	7.97	7.69	11.36	9.01[b]	8.17	7.89	11.57	9.21[ab]
9	Punjab Shyamli	11.00	13.13	8.37	10.83[a]	11.18	13.32	8.57	11.02[a]
10	Yellow Delight	8.67	8.60	9.52	8.93[b]	8.90	8.83	9.75	9.16[ab]
	Mean	7.75[b]	7.70[b]	8.20[a]		7.97[b]	7.89[b]	9.00[a]	

Table 2. Effect of different sources of light as night break on leaf thickness in Korean chrysanthemum.

Sl. No.	Genotype	Leaf thickness (mm)							
		2015			Mean	2016			Mean
		Incandescent bulb	CFL	LED		Incandescent bulb	CFL	LED	
1	Banglori Local	0.64	0.76	0.90	0.77[a]	0.81	0.98	1.14	0.98[a]
2	Boris Becker	0.67	0.56	2.70	1.31[a]	0.86	0.77	2.93	1.52[a]
3	Reagan White	0.66	0.73	0.76	0.72[a]	0.91	0.98	1.02	0.97[a]
4	Kelvin Mandarin	0.90	1.00	0.99	0.96[a]	1.05	1.18	1.23	1.15[a]
5	NBRI Sunil	0.82	0.88	0.99	0.90[a]	0.99	1.05	0.99	1.01[a]
6	Reagan Emperor	0.66	0.83	0.89	0.79[a]	0.82	1.00	1.07	0.96[a]
7	Otome Pink	0.54	0.69	0.75	0.66[a]	0.95	0.84	0.91	0.90[a]
8	Jaya	0.55	0.66	0.72	0.64[a]	0.75	0.86	0.94	0.85[a]
9	Punjab Shyamli	0.62	0.66	0.70	0.66[a]	0.81	0.85	0.90	0.85[a]
10	Yellow Delight	0.41	0.51	0.55	0.49[a]	0.64	0.74	0.78	0.72[a]
Mean		0.65[a]	0.73[a]	0.99[a]		0.86[a]	0.93[a]	1.19[a]	

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. *Significant at $p < 0.05$.

Table 3. Effect of different sources of light as night break on petiole length in Korean chrysanthemum.

Sl. No.	Genotype	Petiole length (mm)							
		2015			Mean	2016			Mean
		Incande-scent bulb	CFL	LED		Incande-scent bulb	CFL	LED	
1	Banglori Local	5.42	6.42	8.40	6.75[g]	6.66	8.04	10.01	8.24[g]
2	Boris Becker	6.41	8.44	14.43	9.76[fe]	6.69	8.80	14.94	10.14[ef]
3	Reagan White	14.92	14.53	11.60	13.68[b]	15.03	14.67	11.87	13.86[b]
4	Kelvin Mandarin	12.16	11.45	14.06	12.56[bc]	12.28	11.60	14.33	12.74[bc]
5	NBRI Sunil	15.75	14.44	14.27	14.82[a]	15.93	14.73	14.63	15.10[a]
6	Reagan Emperor	14.72	14.38	9.68	12.93[bc]	14.90	14.67	9.99	13.19[bc]
7	Otome Pink	9.24	9.32	10.27	9.61[f]	9.38	9.50	10.61	9.83[f]
8	Jaya	8.31	10.88	13.32	10.84[de]	8.53	11.09	13.67	11.10[de]
9	Punjab Shyamli	14.36	14.00	7.03	11.80[cd]	14.52	14.24	7.35	12.04[cd]
10	Yellow Delight	7.01	6.67	6.38	6.69[g]	7.10	6.79	6.60	6.83[h]
Mean		10.83[a]	11.05[a]	10.94[a]		11.10[a]	11.41[a]	11.40[a]	

Table 4. Effect of different sources of light as night break on leaf area index in Korean chrysanthemum.

Sl. No.	Genotype	Leaf area index							
		2015			Mean	2016			Mean
		Incande-scent bulb	CFL	LED		Incande-scent bulb	CFL	LED	
1	Banglori Local	0.47	0.50	0.55	0.51[a]	0.49	0.51	0.54	0.51[b]
2	Boris Becker	0.46	0.51	0.53	0.50[a]	0.49	0.52	0.54	0.52[b]
3	Reagan White	0.47	0.50	0.53	0.50[a]	0.49	0.51	0.52	0.51[b]
4	Kelvin Mandarin	0.39	0.38	0.47	0.41[a]	0.40	0.37	0.46	0.41[b]
5	NBRI Sunil	0.41	0.39	0.24	0.35[b]	0.40	0.39	0.23	0.34[b]
6	Reagan Emperor	0.37	0.43	0.42	0.41[a]	0.36	0.42	0.43	0.40[b]
7	Otome Pink	0.38	0.36	0.39	0.38[b]	0.34	0.37	0.38	0.36[b]
8	Jaya	0.50	0.52	0.51	0.51[a]	0.51	0.51	0.53	0.52[a]
9	Punjab Shyamli	0.57	0.59	0.60	0.59[a]	0.59	0.58	0.62	0.60[a]
10	Yellow Delight	0.40	0.40	0.42	0.41[a]	0.40	0.42	0.42	0.43[b]
Mean		0.44[a]	0.46[a]	0.47[a]		0.45[a]	0.46[a]	0.47[a]	

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT.
*Significant at $p < 0.05$.

the light sources among the various genotypes showed significant difference. The leaf thickness during 2015 and 2016 was recorded maximum (0.96 and 1.15 mm, respectively) in Kelvin Mandarin (Table 2) whereas Yellow Delight exhibited minimum leaf thickness (0.49 and 0.72 mm, respectively during 2015 and 2016). For both years petiole length was found maximum (14.82 and 15.10 mm, respectively) in NBRI Sunil whereas, Otome Pink exhibited shortest petiole (Table 3). Similar variation was observed for leaf area index with maximum (0.59 and 0.60) in Punjab Shyamli which was at par with Jaya for both the years (Table 4). Night break using LED lights have resulted in highest partitioning coefficient during 2015 and 2016 (30.50 and 31.50, respectively) whereas, it was recorded lowest (28.83 and 29.75) in incandescent bulb (Table 5).

Genotype Otome Pink exhibited highest partitioning coefficient for both years (43.60 and 44.48). The partitioning coefficient indicates the amount of photosynthetic assimilates utilized for the development of flower buds and flowers (Kaur 2014). Higher values indicate that most of the carbohydrates assimilated through photosynthesis have been used up for the development of the flowers. Leaf weight ratio was recorded maximum (0.255 and 0.306) in Boris Becker for both the years (Table 6). These results are attributed to the genetic make of the plants as the various genotypes have exhibited a non-consistent response. Kaur (2014) have also found the variations in

Table 5. Effect of different sources of light as night break on partitioning coefficient in Korean chrysanthemum.

Sl. No.	Genotype	Partitioning coefficient							
		2015			Mean	2016			Mean
		Incande-scent bulb	CFL	LED		Incande-scent bulb	CFL	LED	
1	Banglori Local	24.70	25.20	26.93	25.61[f]	25.58	26.08	27.82	26.49[f]
2	Boris Becker	22.60	23.33	25.67	23.87[g]	23.55	24.29	26.62	24.82[g]
3	Reagan White	24.00	25.03	26.50	25.18[f]	24.88	25.92	27.38	26.06[f]
4	Kelvin Mandarin	39.90	39.08	39.90	39.63[b]	40.85	40.04	40.85	40.58[b]
5	NBRI Sunil	24.70	27.07	30.67	27.48[e]	25.58	27.95	31.55	28.36[e]
6	Reagan Emperor	30.07	29.47	28.13	29.22[d]	31.02	30.42	29.09	30.18[d]
7	Otome Pink	42.20	43.67	44.93	43.60[a]	43.08	44.55	45.82	44.48[a]
8	Jaya	19.70	19.23	20.07	19.67[h]	20.65	20.19	21.02	20.62[h]
9	Punjab Shyamli	31.17	31.43	32.57	31.72[c]	32.05	32.32	33.45	32.61[c]
10	Yellow Delight	29.30	29.90	30.43	29.88[d]	30.25	30.85	31.39	30.83[d]
	Mean	28.83[c]	29.34[b]	30.50[a]		29.75[c]	30.26[b]	31.50[a]	

Table 6. Effect of different sources of light as night break on leaf weight ratio in Korean chrysanthemum.

Sl. No.	Genotype	Leaf weight ratio							
		2015			Mean	2016			Mean
		Incande-scent bulb	CFL	LED		Incande-scent bulb	CFL	LED	
1	Banglori Local	0.173	0.215	0.235	0.208[a]	0.222	0.266	0.289	0.259[a]
2	Boris Becker	0.195	0.200	0.235	0.210[a]	0.244	0.252	0.289	0.262[a]
3	Reagan White	0.250	0.251	0.265	0.255[a]	0.299	0.302	0.317	0.306[a]
4	Kelvin Mandarin	0.175	0.179	0.232	0.195[a]	0.215	0.216	0.278	0.236[a]
5	NBRI Sunil	0.168	0.173	0.215	0.185[a]	0.208	0.212	0.223	0.214[a]
6	Reagan Emperor	0.162	0.171	0.178	0.170[a]	0.199	0.213	0.221	0.211[a]
7	Otome Pink	0.415	0.152	0.152	0.240[a]	0.479	0.189	0.190	0.286[a]
8	Jaya	0.193	0.195	0.212	0.200[a]	0.244	0.246	0.264	0.251[a]
9	Punjab Shyamli	0.182	0.185	0.200	0.189[a]	0.241	0.244	0.262	0.249[a]
10	Yellow Delight	0.232	0.225	0.225	0.227[a]	0.272	0.267	0.271	0.270[a]
	Mean	0.215[a]	0.195[a]	0.215[a]		0.262[a]	0.241[a]	0.260[a]	

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT.
*Significant at $p< 0.05$

Table 7. Effect of different sources of light as night break on number of stomata per unit area in Korean chrysanthemum.

Sl. No.	Genotype	Number of stomata per unit area (mm^2)							
		2015			Mean	2016			Mean
		Incande-scent bulb	CFL	LED		Incande-scent bulb	CFL	LED	
1	Banglori Local	52.33	43.90	52.18	49.47^b	52.51	44.12	52.42	49.68^b
2	Boris Becker	50.80	52.97	56.97	53.58^a	50.99	53.17	57.21	53.79^a
3	Reagan White	51.67	47.14	57.418	52.08^a	49.58	55.45	56.67	53.90^a
4	Kelvin Mandarin	44.07	50.27	55.64	49.99^b	44.24	50.4	55.87	50.17^b
5	NBRI Sunil	49.33	55.20	56.40	53.64^a	51.84	47.31	63.42	54.19^a
6	Reagan Emperor	50.33	54.27	55.07	53.22^a	50.50	54.44	55.25	53.40^a
7	Otome Pink	46.20	55.43	57.32	52.98^a	46.62	55.59	57.47	53.23^a
8	Jaya	46.13	53.03	55.91	51.69^b	46.33	53.23	56.12	51.89^{ab}
9	Punjab Shyamli	44.00	54.33	57.85	52.06^b	44.18	54.52	58.05	52.25^a
10	Yellow Delight	42.17	56.67	56.00	51.61^b	42.40	56.89	56.23	51.84^a
	Mean	47.70^c	52.33^b	56.08^a		47.92^c	52.51^b	56.87^a	

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. *Significant at $p < 0.05$.

Table 8. Effect of different sources of light as night break on anthocyanin content in Korean chrysanthemum.

Sl. No.	Genotype	Anthocyanins (mg/g)							
		2015			Mean	2016			Mean
		Incande-scent bulb	CFL	LED		Incande-scent bulb	CFL	LED	
1	Banglori Local	ND	ND	ND	ND^f	ND	ND	ND	ND^f
2	Boris Becker	11.89	10.45	14.11	12.15^b	12.46	10.68	14.42	12.52^b
3	Reagan White	ND	ND	ND	ND^f	ND	ND	ND	ND^f
4	Kelvin Mandarin	1.45	1.61	2.69	1.92^d	1.63	1.81	2.80	2.08^d
5	NBRI Sunil	ND	ND	ND^f	ND^f	ND	ND	ND	ND^f
6	Reagan Emperor	2.13	2.09	5.08	3.10^c	2.45	2.30	5.22	3.32^c
7	Otome Pink	0.58	0.53	1.49	0.87^e	0.67	0.60	1.65	0.97^e
8	Jaya	61.44	63.41	66.08	63.64^a	62.50	63.96	66.93	64.46^a
9	Punjab Shyamli	0.15	0.16	0.53	0.28^f	0.17	0.17	0.62	0.32^f
10	Yellow Delight	ND	ND	ND	ND^f	ND	ND	ND	ND^f
	Mean	7.76^b	7.83^b	8.99^a		7.99^b	7.95^b	9.16^a	

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. *Significant at $p< 0.05$. ND = Not detected.

these parameters mostly due to genetic constitution of the genotypes under study. The number of stomata per mm^2 (Table 7) was found maximum (56.60 and 56.87 per mm^2) under LED source of light as compared to other two sources of light used for the experiment during 2015 and 2016. Zheng and Van Labeke (2017) have also reported the high stomatal index under different qualities of light from LED source on some ornamental plants. From Tables 8 and 9 it is evident that LED lights were more effective in enhancing the anthocyanins and carotenoids content based on which the genotypes can be grouped into high and low anthocyanin and carotenoids, with maximum anthocyanins in genotype Jaya and carotenoids in Boris Becker. These findings are in accordance with the results reported by Mizuno *et al.* (2011) who have also reported increased anthocyanin and carotenoid contents in cabbage leaves grown under LED lights. Chang *et al.* (2015) have

Table 9. Effect of different sources of light as night break on carotenoids content in Korean chrysanthemum.

Sl. No.	Genotype	Carotenoids (mg/g)							
		2015			Mean	2016			Mean
		Incande-scent bulb	CFL	LED		Incande-scent bulb	CFL	LED	
1	Banglori Local	8.16	8.64	9.65	8.82[h]	8.48	8.94	9.96	9.13[h]
2	Boris Becker	57.21	55.45	59.97	57.54[a]	57.51	55.77	60.28	57.85[a]
3	Reagan White	33.11	32.84	37.91	34.62[d]	33.34	33.10	38.16	34.87[d]
4	Kelvin Mandarin	6.75	6.92	8.10	7.26[i]	6.98	7.11	8.33	7.47[i]
5	NBRI Sunil	8.69	9.07	11.77	9.84[g]	8.93	9.28	11.99	10.07[g]
6	Reagan Emperor	36.34	38.17	40.36	38.29[c]	36.54	38.42	40.61	38.52[c]
7	Otome Pink	54.61	51.88	59.28	55.26[b]	54.83	52.09	59.51	55.48[b]
8	Jaya	5.07	5.04	6.00	5.37[j]	5.39	5.35	6.31	5.68[j]
9	Punjab Shyamli	24.77	25.27	32.22	27.42[e]	25.18	25.66	32.64	27.83[e]
10	Yellow Delight	12.79	12.77	15.84	13.80[f]	12.96	12.96	16.07	14.00[f]
	Mean	24.75[b]	24.60[b]	28.11[a]		25.01[b]	24.87[b]	28.39[a]	

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT.
*Significant at $p < 0.05$

evaluated large germplasm of chrysanthemum for anthocyanins and carotenoids depicting large differences due to its genetic makeup. Most cultivars that were classified as ND (Non-detectable) or low level showed faint/pale coloured or white coloured petals. It was reported that the biosynthesis of carotenoids could impart white colours to petals in chrysanthemums, since the component was subsequently degraded to colourless compounds by a factor, carotenoid cleavage dioxygenase (Ohmiya 2006). It can be inferred from the two years data that LED lights can be used as an ideal source of light for night break in Korean chrysanthemum to influence the growth patterns which largely contribute to the flower production. From this study, it may be concluded that LED lights used for NB treatment for delay of flowering can effectively influence the growth attributes of Koren chrysanthemum.

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