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EFFECT OF DIFFERENT SOURCES OF LIGHT AS NIGHT BREAK ON GROWTH AND FLOWERING OF KOREAN CHRYSANTHEMUM (*Chrysanthemum morifolium* Ramat.) GENOTYPES

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ABSTRACT
Korean chrysanthemum occupies the prominent position in world trade of cut flowers. As chrysanthemum is classified as short-day plant, flower bud initiation is highly controlled by prevailing photoperiods which have marked influence on flower production. Extended photoperiods are generally provided to delay flower bud initiation as Night Break (NB) treatment instead of continuous lighting to save energy. The present study was aimed to compare the effect of three (Incandescent bulbs, Compact fluorescent lights and light emitting diodes-LED) sources of light as NB treatment on ten genotypes of chrysanthemum belonging to Korean group. The night break treatment with LED lights resulted in increased plant height (66.85 and 67.76 cm) and plant spread (25.73 and 26.65cm) during 2015 and 2016 respectively. The Flowering was significantly delayed (148.34 and 149.25 days) under the NB induced by LED lights as compared to other two sources of light used for the study. Internodal length was recorded maximum (8.20 and 9.00 mm) under LED lights. Similar trends were recorded for number of flowers per plant, flower size and vase life. However, none of the source of light could affect significantly the number of branches per plant. Different genotypes showed varied response towards NB treatment as the flower bud appearance was recorded earliest (136.93 and 137.89 days) in Yellow Delight while in Punjab Shyamli it was significantly delayed (193.57 and 193.48 days). It is thus concluded that LED lights are more effective when intending to photoperiodic delay of the flowering in Korean chrysanthemum compared to other sources of light used.

INTRODUCTION

Korean chrysanthemum (*Chrysanthemum morifolium* Ramat.) belongs to the family Asteraceae is the commercial flower which is grown for cut flowers, loose flowers, pot mum as well as bedding plant. Flowering in *Chrysanthemum morifolium* Ramat. is photperiodically controlled as it is a qualitative short-day plant that requires 14.5 h photoperiod for flower initiation and 13.5 h light period for bud development (Runkle and Fisher, 2004). This unique property of the plant is being exploited worldwide for flower regulation or production during a particular period as per the market demand (Datta and Gupta,2012). Night break (NB) effect is widely used in chrysanthemum production by applying incandescent lamps to inhibit flowering of chrysanthemum in order to obtain longer shoots. Under North Indian conditions it usually flowers during November -December, however, flowering can be delayed by providing additional photoperiod hours as the flowers under non-inductive photoperiods continues to grow vegetatively. Longer photoperiods are provided as NB which essentially divides the long dark period into two small nights of less than seven hours, thus inhibiting the flower bud formation and the plants remain in vegetative phase only (Cathey and Borthwick,1964). For the 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). Therefore, keeping this in view the effect of different sources of light on plant growth and flowering, the present study was under taken to compare the effect of incandescent bulbs, fluorescent tube lights and LED lights for NB on flower induction in Chrysanthemum genotypes belonging to Korean group.

MATERIALS AND METHODS

The study was conducted 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 rottened farm yard manure (2:1) along with diammonium phosphate @0.5 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 hours after 15th August. The NB treatment was provided by using three sources of light viz. incandescent bulbs, CFL (Compact Fluorescent light-Crompton Groove make) and LED (Light emitting diodes-Philips make) lamps of approximately same wattage for two hours from 10.00 pm 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 flower parameters, Plant height(cm), Plant spread (cm), number of branches per plant, internodal length (mm), days taken for bud appearance, days to flowering, flower size (cm) number of flowers per plant and flower vase life(days). Experiment was laid out with three replications consisting five pots each, in completely randomized design for the years 2015 and 2016. Statistical analysis was performed using SAS software and the means were compared using Duncan Multiple Range Test (DMRT) at 5% level of significance.

RESULTS

Plant height(cm)

The highest plant height among various sources of light for NB was recorded 66.85 cm and 67.76 cm with LED during 2015 and 2016, respectively which was found to be at par with that of CFL lights, whereas, the lowest plant height was observed with incandescent bulb. Among the genotypes, on averaging across the different sources of light, significantly the highest plant height (83.81, 84.77) was observed in genotype Boris Becker, conversely the minimum plant height was recoded in genotype Otome Pink (53.92, 54.80) during the same period.

Plant spread(cm)

The plant spread among the different sources of light for night break was recorded maximum 25.73 cm and 26.65 cm with LED lights during 2015 and 2016 respectively (Table 2). Plants given NB treatment with incandescent bulb exhibited lowest plant spread, 20.80 cm and 21.72 cm, during 2015 and 2016, respectively. Among the genotypes, the, mean of the various sources of light, significantly the highest plant spread (34.51, 36.44) was observed in genotype Jaya, whereas, it was minimum in genotype Banglori Local (16.64, 17.62) which was at par with genotype Boris Becker (16.69, 17.86) during 2015 and 2016, respectively.

Number of branches per plant

The number of branches per plant among the different sources of light for night break was recorded non-significant in both years (Table 3). However, among the genotypes, significantly the highest number of branches per plant (4.66, 5.32) was observed in genotype Punjab Shyamli during 2015 and 2016. The minimum number of branches per plant (1.74, 2.40) was found in genotype Otome Pink during the same period of study.

Internodal length (mm)

Night break with LED lights resulted in increased internodal length as compared to CFL and Incandescent bulbs (Table 3). It was recorded that distance between two consecutive nodes was maximum (8.20 and 9.00) with LED. However, it was found to be lowest the lowest (7.70 and 7.89) with CFL

Days taken for flower bud appearance and flowering

Sources of light had significant effect on days taken for flower bud appearance (Table 4). All the three sources were effective to delay the flower bud appearance but it was recorded maximum (148.34, 149.25 days) with LED source of light, however, the lowest number (142.68, 143.60 days) of days were observed with incandescent bulb during 2015 and 2016, respectively. The genotypes, also showed varied response towards the sources of light. Since the application of night break treatment using three different sources of light has resulted in delay in flower bud appearance, the days taken to flowering were also affected significantly (Table 5). Similar trends were recorded for the influence of source of light as well as response of various genotypes for days taken to flowering.

Number of flowers per plant

The highest number of flowers per plant among the different sources of light for night break was 34.35 and 35.52 with LED

Table 1: Effect of different sources of light as night break on plant height in Korean chrysanthemum

S. No	Genotype	Plant height (cm) 2015 Incandescent bulb	CFL	LED	Mean	2016 Incandescent bulb	CFL	LED	Mean
1	Banglori Local	54.22	59.18	60.42	57.94^{de}	55.10	60.06	61.31	58.82^{de}
2	Boris Becker	85.59	81.67	84.18	83.81^{a}	86.54	82.63	85.13	84.77^{a}
3	Reagan White	56.02	58.33	59.26	57.87^{de}	56.90	59.21	60.15	58.75^{de}
4	Kelvin Mandarin	61.66	63.32	65.21	63.40^{cd}	62.61	64.26	66.16	64.34^{cd}
5	NBRI Sunil	64.24	63.76	66.74	64.91^{cd}	65.12	64.65	67.62	65.80^{cd}
6	Reagan Emperor	60.58	61.34	62.66	61.53^{cd}	61.54	62.29	63.61	62.48^{cd}
7	Otome Pink	51.42	51.83	58.50	53.92^{e}	52.30	52.71	59.38	54.80^{e}
8	Jaya	73.69	74.23	75.77	74.56^{b}	74.65	74.82	76.72	75.40^{b}
9	Punjab Shyamli	63.21	64.55	66.74	64.83^{cd}	64.09	65.44	67.62	65.72^{cd}
10	Yellow Delight	66.41	67.12	69.00	67.51^{c}	67.36	68.07	69.96	68.46^{c}
Mean		63.70b	64.53^{ab}	66.85^{a}		64.62^{b}	65.42^{ab}	67.76^{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 2: Effect of different sources of light as night break on plant spread in Korean chrysanthemum

S. No.	Genotype	Plant spread (cm) 2015 Incandescent bulb	CFL	LED	Mean	2016 Incandescent bulb	LED	CFL	Mean
1	Banglori Local	15.11	16.33	18.48	16.64^{i}	15.99	17.52	19.36	17.62^{i}
2	Boris Becker	21.29	22.66	25.51	23.15^{d}	22.24	24.10	26.46	24.27^{d}
3	Reagan White	15.85	15.84	18.37	16.69^{j}	16.73	17.57	19.26	17.86^{j}
4	Kelvin Mandarin	16.63	18.55	19.58	18.25^{h}	17.58	19.20	20.53	19.10^{h}
5	NBRI Sunil	17.50	19.51	25.40	20.80^{g}	18.39	21.69	26.29	22.12^{g}
6	Reagan Emperor	24.79	27.64	21.45	24.63^{c}	25.74	25.58	22.40	24.57^{c}
7	Otome Pink	22.35	20.38	22.51	21.75^{f}	23.23	22.63	23.39	23.08^{f}
8	Jaya	33.53	31.60	38.41	34.51^{a}	34.49	35.48	39.36	36.44^{a}
9	Punjab Shyamli	22.65	32.57	41.10	32.11^{b}	23.53	32.99	41.99	32.84^{b}
10	Yellow Delight	18.37	21.54	26.51	22.14^{e}	19.32	23.09	27.47	23.29^{e}
Mean		20.80^{c}	22.67^{b}	25.73^{a}		21.72^{c}	23.98^{b}	26.65^{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 number of branches per plant in Korean chrysanthemum

S. No.	Genotype	Number of branches/plant 2015 Incandescent bulb	CFL	LED	Mean	2016 Incandescent bulb	CFL	LED	Mean
1	Banglori Local	2.19	2.12	2.09	2.13^{e}	S1	S2	S3	Mean
2	Boris Becker	2.75	2.77	2.81	2.78^{c}	2.83	2.89	2.99	2.90^{def}
3	Reagan White	2.70	2.70	2.76	2.72^{c}	3.41	3.34	5.50	4.08^{bc}
4	Kelvin Mandarin	2.80	2.72	2.78	2.77^{c}	3.36	3.44	3.52	3.44^{cde}
5	NBRI Sunil	2.44	2.44	2.42	2.43^{d}	3.67	3.72	3.78	3.72^{bcd}
6	Reagan Emperor	2.12	2.02	2.02	2.05^{e}	3.25	3.32	3.40	3.32^{cde}
7	Otome Pink	1.75	1.73	1.75	1.74^{f}	2.28	2.41	2.50	2.40^{f}
8	Jaya	3.70	3.69	3.76	3.72^{b}	4.25	4.35	4.48	4.36^{b}
9	Punjab Shyamli	4.69	4.63	4.65	4.66^{a}	5.32	5.29	5.34	5.32^{a}
10	Yellow Delight	2.06	2.11	2.09	2.09^{e}	2.78	2.85	2.91	2.85^{def}
Mean		2.72^{a}	2.69^{a}	2.71^{a}		2.46^{a}	2.62^{a}	2.63^{a}	

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

during 2015-2016, respectively (Table 6), whereas, the lowest number of flowers per plant was 29.91 and 32.66 with incandescent bulb which was recorded at par with CFL. Among the genotypes, highest number of flowers per plant (61.31, 54.42) was observed in genotype Jaya.

Flower size (cm)

Flower size was recorded maximum (6.85 cm, 7.13 cm) under LED light treatment during whereas, plants under CFL exhibited lowest flower size (6.10 cm, 6.36 cm), however, it was at par with that of the values observed under incandescent bulb (Table 7). Among the genotypes, the average across the different sources of light, significantly the highest flower size (8.07 cm, 8.47 cm) was recorded in genotype Punjab Shyamli whereas, Kelvin Mandarin exhibited lowest (4.04 cm, 4.26 cm) flower size.

Vase life (days)

The flowers harvested from the plants subjected to NB treatment with LED lights exhibited maximum (12.27 and 12.55 days) vase life (Table 8), whereas, the lowest days (10.69 and 10.96 days) was recorded in incandescent bulb which was found at par with that of CFL treatment. Genotype Reagan Emperor showed maximum (14.37 and 14.60 days) vase life followed by Reagan White (12.53 and 12.78 days) for both the years.

DISCUSSION

It has been reported that for commercial production of chrysanthemum cut stems, it is required to maintain plants in vegetative state both for rapid growth and to attain the desired stem length before flower induction because the long stems fetch high prices in the market Vegetative growth in chrysanthemum genotype grown for year around flowering is promoted by long day conditions. The increased plant height and spread are the results of enhanced photosynthetic activities of the plants, thus accompanied by accumulation of more carbohydrates under longer photoperiodic conditions provided as NB treatments.The results obtained are in accordance with those as reported by Datta and Ramadas (2000). The internodal length observed under all the three treatments was significant, however, these results are in contradiction with those reported by Kumar and Singh (2017), as they have reported non-significant effect of extended photoperiods on internodal length in chrysanthemum genotype Zembla.

Delay in bud formation and flower development and thus, days to flower in chrysanthemum by using long photoperiods with various sources of light has been reported by many workers. Plants regulate their flowering by transducing the

Table 4: Effect of different sources of light as night break on internodal length in Korean chrysanthemum

S. No.	Genotype	Internodal length (mm) 2015 Incandescent bulb	CFL	LED	Mean	2016 Incandescent bulb	CFL	LED	Mean
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 5: Effect of different sources of light as night break on days taken for bud appearance in Korean chrysanthemum

S. No.	Genotype	Days taken for bud appearance 2015 Incandescent bulb	CFL	LED	Mean	2016 Incandescent bulb	CFL	LED	Mean
1	Banglori Local	141.06	144.73	150.69	145.49^{cd}	141.95	145.61	151.57	146.38^{ef}
2	Boris Becker	152.06	153.79	158.07	154.64^{b}	153.02	154.74	159.02	155.59^{b}
3	Reagan White	143.33	147.17	148.70	146.40^{c}	144.21	148.05	149.59	147.28^{de}
4	Kelvin Mandarin	140.44	150.54	150.43	147.14^{c}	141.39	151.49	151.38	148.09^{c}
5	NBRI Sunil	136.68	134.08	141.20	137.32^{g}	137.56	134.96	142.08	138.20^{i}
6	Reagan Emperor	143.58	143.43	145.34	144.12^{de}	144.53	144.38	146.29	145.07^{fg}
7	Otome Pink	137.91	137.17	144.30	139.79^{f}	138.79	138.05	145.18	140.67^{h}
8	Jaya	141.47	142.28	145.40	143.05^{e}	142.42	143.23	146.35	144.00^{g}
9	Punjab Shyamli	155.07	157.19	159.23	157.16^{a}	155.95	158.07	160.11	158.04^{a}
10	Yellow Delight	135.23	135.57	140.00	136.93^{g}	136.19	136.52	140.95	137.89^{i}
Mean		142.68^{c}	144.60^{b}	148.34^{a}		143.60^{c}	145.51^{b}	149.25^{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 6: Effect of different sources of light as night break on days taken for flowering in Korean chrysanthemum

S. No.	Genotype	Days to flowering 2015 Incandescent bulb	CFL	LED	Mean	2016 Incandescent bulb	CFL	LED	Mean
1	Banglori Local	168.25	172.71	179.97	173.64^{d}	161.31	174.76	182.16	172.74^{f}
2	Boris Becker	180.84	182.98	188.19	184.00^{b}	183.02	185.16	190.37	186.18^{b}
3	Reagan White	173.35	176.62	179.04	176.34^{c}	175.31	178.58	181.05	178.31^{c}
4	Kelvin Mandarin	169.63	180.65	179.29	176.52^{c}	172.12	182.69	181.30	178.70^{c}
5	NBRI Sunil	157.76	159.16	167.37	161.43^{f}	160.39	161.76	169.61	163.92^{g}
6	Reagan Emperor	173.63	174.13	177.46	175.07^{cd}	176.0	176.30	179.96	177.42^{cd}
7	Otome Pink	178.75	170.01	178.12	175.63^{d}	173.50	171.40	179.61	174.84^{e}
8	Jaya	167.35	167.32	172.60	169.09^{e}	169.28	169.27	174.55	171.03^{f}
9	Punjab Shyamli	188.39	191.14	193.57	191.03^{a}	190.82	193.544	196.07	193.48^{a}
10	Yellow Delight	159.94	161.32	165.36	162.21^{f}	161.71	162.97	167.12	163.93^{g}
Mean		165.79^{c}	173.60^{b}	178.10^{a}		172.35^{c}	175.64^{b}	180.18^{a}	

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

light signal into the circadian clock that controls the constans (CO) protein, a promoter activating the expression of the *flowering locus t* (*FT*) gene, which encodes a florigen under inductive conditions (Yanovsky and Kay, 2002). Similar results have been postulated by Fukai (2003) while investigating the effect of photoperiod (artificial long days through night break/ continuous lighting) on chrysanthemum found that 14 h photoperiods inhibited flowering in and autumn flowering genotypes of chrysanthemum. The LED lights were found more effective in inhibiting the flower bud formation thereby regulation of cut flower supply in the market as they have typical discrete spectral properties which make them highly

Table 7: Effect of different sources of light as night break on flower size in Korean chrysanthemum

S. No.	Genotype	Flower size(cm) 2015 Incandescent bulb	CFL	LED	Mean	2016 Incandescent bulb	CFL	LED	Mean
1	Banglori Local	5.86	5.30	6.96	6.04^{e}	6.18	5.60	7.27	6.35^{e}
2	Boris Becker	6.33	5.97	6.50	6.27^{e}	6.63	6.29	6.80	6.57^{e}
3	Reagan White	7.53	7.80	7.96	7.76^{ab}	7.77	8.06	8.22	8.02^{b}
4	Kelvin Mandarin	3.46	3.63	5.03	4.04^{g}	3.69	3.83	5.26	4.26^{g}
5	NBRI Sunil	4.50	4.50	5.60	4.87^{f}	4.73	4.71	5.83	5.09^{f}
6	Reagan Emperor	7.20	7.53	7.50	7.41^{c}	7.40	7.78	7.75	7.64^{c}
7	Otome Pink	5.07	4.40	5.63	5.03^{f}	5.29	4.62	5.86	5.26^{f}
8	Jaya	7.23	7.30	8.00	7.51^{bc}	7.55	7.61	8.31	7.82^{bc}
9	Punjab Shyamli	8.17	8.07	7.96	8.07^{a}	8.57	8.46	8.39	8.47^{a}
10	Yellow Delight	6.43	6.50	7.33	6.75^{d}	6.61	6.69	7.56	6.95^{d}
Mean		6.18^{b}	6.10^{b}	6.85^{a}		6.44^{b}	6.36^{b}	7.13^{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 vase life in Korean chrysanthemum

S. No.	Genotype	Vase life (days) 2015 Incandescent bulb	CFL	LED	Mean	2016 Incandescent bulb	CFL	LED	Mean
1	Banglori Local	9.67	10.45	12.58	10.90^{c}	9.98	10.76	12.89	11.21^{c}
2	Boris Becker	8.40	8.33	9.00	8.58^{e}	8.70	8.65	9.30	8.88^{e}
3	Reagan White	12.39	11.65	13.55	12.53^{b}	12.62	11.91	13.80	12.78^{b}
4	Kelvin Mandarin	12.44	11.93	14.65	13.01^{b}	12.67	12.17	14.88	13.24^{b}
5	NBRI Sunil	8.70	9.73	11.08	9.84^{d}	8.93	9.95	11.31	10.06^{d}
6	Reagan Emperor	13.50	13.83	15.78	14.37^{a}	13.70	14.08	16.03	14.60^{a}
7	Otome Pink	9.20	8.63	11.65	9.83^{d}	9.42	8.85	11.88	10.05^{d}
8	Jaya	10.77	10.92	10.77	10.82^{c}	11.09	11.23	11.08	11.13^{c}
9	Punjab Shyamli	12.58	13.55	11.89	12.67^{b}	12.99	13.95	12.32	13.09^{b}
10	Yellow Delight	9.32	9.40	11.75	10.16^{d}	9.49	9.59	11.98	10.35^{d}
Mean		10.69^{b}	10.84^{b}	12.27^{a}		10.96^{b}	11.11^{b}	12.55^{a}	

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. *Significant at $p < 0.0$

suitable for flower development at specific growth stages for providing optimal light Schamp *et al*. (2012)

The increase in number of flowers per plant, flower size and vase life under LED lights may be attributed to increased photosynthetic activity under LED lights as compared to other sources of light due to the discrete spectral properties of LED lights which might have resulted in high carbohydrate synthesis with enhanced mobilization of the assimilates by young sink tissues of growing lateral shoots.) However, the variation in flower size partially may be attributed to the genetic makeup of the plant. These findings are in consonance with the findings of El-Antably *et al*. (1991). The increased enzymatic activity of catalase and peroxidase under increased photoperiods is reported for the senescence of cut flowers during vase life studies (Rafath and Khan, 2007). From the present study, it is thus concluded that NB treatment for flower bud inhibition in chrysanthemum using LED lights is most effective to maintain quality of the Korean chrysanthemum.

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