Effects of Different Supplemental Lighting Sources on Chrysanthemum Growth and Flower Quality in Open-Field Conditions

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Abstract

Chrysanthemum is a short-day flower that only induces flower bud initiation and development in short day-length condition. Night-interuption is used to break long night condition and is considered as a useful flower manipulation technique. Plants with supplemental lighting treatment are inhibited to move to flowering stage, thus facilitating growth and obtaining higher flower quality. LEDs are an advanced lighting system that emits appropriate light spectrum for the plant, which is not a characteristic of other systems such as incandescent and compact lights. In-vitro and greenhouse experiments showed that LED lighting at night is of great benefit for *Chrysanthemum* culturing. In this paper, the effects of LED lighting source toward plants growing under open-field conditions will be discussed.

Keywords*: Chrysanthemum, Compact, Incandescent, Light emitting diode (LED)*

Introduction

Chrysanthemum is one of the most important cut flowers in Vietnam, especially during lunar new year or Tet holiday. In the North central region of Vietnam, the major difficulty when growing this flower in winter season comes from extreme weather condition including extensive cold and wet. Since most farmers still use tranditional cultivation techniques, the yield and quality of the flower can not be improved. In the market, local products cannot compete with flower transported from other provinces although the price of imported flowers was substantially higher due to transportation cost. In addition, annual fluctuations in climate make it hard to predict the flowering time of the *Chrysanthemum*, therefore flowers often bloom earlier or later than desired date, thus fetching a low price.

For *Chrysanthemum*, flower bud initiation is strictly regulated by photoperiod, which can be manipulated by artificial lighting. *Chrysanthemum* is a short-day plant which means that flowers are only induced when the day-lengths are shorter than the critical day-length [5]. In winter, *Crysanthemum* often sets flowers earlier due to short day-length, thus, have low heights. While supplemental lighting for several hours before sunset can help extend the length of day, lighting for several hours at night will break the long night, which will also have the same effects as in long-day conditions. These techniques have been successfully applied at big farms in Lam Dong province of Vietnam. The products have longer stems and bigger buds and flowers. Among various lighting sources, LED (Light Emitting Diot) is more advantagous for many reasons. LED bulbs not only have longer life-expectancy but also are more energetically efficient. Moreover, due to the fact that plants can only absorb certain wavelengths of visible light and different plants prefer different spectrum, one can optimize plant growth by using LEDs emitting desired spectrum [3], [4], [6], [8], [9].

In order to promote flowers production in winter season at the North central regions, we conducted a project in November of 2017 at Thua Thien Hue province where we applied supplemental LED (Light Emitting Diode) lighting to grow the *Chrysanthemum morifolium* Ramat. Flowers was aimed to harvest just right before the lunar new year. Growth parameters

were collected to investigate the effectiveness of the technique in open-field condition, in comparison with incandescent and compact lightings and will be presented in this paper.

Materials and Methods

Plant materials, field site and experimental set-up

Chrysanthemum morifolium Ramat seedling-cuttings were planted and grown on medium textured soils at Huong Ho commune, Huong Tra district, Thua Thien Hue province from 1st October to 28th December according to lunar calender. The cultivation practices including watering, fertilizing, pest, weed and diseases controllings were the same as normal practices that have been done previously. The plants were spaced 15 x 15cm apart in 5-6 rows on 20-30cm high raised beds.

Lamps and lightings

Twenty four 9W LEDs (for agriculture purposes, Rang Dong Plastic JSC) or 20W compact florescent or 60W incandescent light bulbs were used for this field-trial. The light bulbs were hanged 2 meters above the ground, 2.6 meters apart, making one row in the middle of each beds. The light had been turned on automatically, using programmable digital power timer, from 10 p.m to 2 a.m (4 hours) every night for one month starting from day 5th after planting. There are three plots (50 m^2 each) for three types of light sources including LED, incandescent and compact. Each plot was separated from each other using dark cloth.

Growth parameters

The growth parameters were measured every week starting from the beginning using a millimetric ruler. Upon each plot, thirty plants were randomly selected for measurements. Parameters related to flower were watched after first flower bud initiated onwards. The height of plants was measured from the soil surface to the tip of the shoot. Stem diameters were also measured at the main stems at the position that were just above the soil. The number of leaves per plant was counted. Leaf blade length was measured from leaf base to leaf tip and excluding the petioleof fully expanded leaf in the middle of the plant. In that same leaf, its width was also studied by measuring the leaf at the widest part. The date at which first flowering bud appeared was recorded. Finally, the quantity of flowers per plant was estimated and the diameter of the main flowers was determined at the harvesting day. The total number of qualified plants for harvesting was calculated in the whole areas. Plants standardized for harvesting were those having straight stems, with at least 4 bloomed buds. The remaining buds were not deformed. Leaves were regular, green and intact.

Results

Chrysanthemum plants were grown with light supplementation at night for 1 months then stopped and were harvested about 2 months later. Growth parameters were collected and presented in table 1 to 5. From table 1, it is noted that the LED lighting system performed better than other lighting systems in term of flower quantity and quality improvements. The total number of flowering plants was highest on the plot using LEDs (90%) whereas on plots using other type of light, the number were 2-3% lower. Also, the number of plants qualified for harvesting was 6 to 11% higher in LED lighting system than other systems.

Table 2 shows the dynamics of plant height and stem diameter of the *Chrysanthemum* growing in different light conditions for night interruptions. Plant height is a critical characteristic, which not only depends on genetics but also largely controlled by environmental conditions. The results show that in the first weeks after planting, there was no statistically significant difference in the height of the flower plants in all experimental set-ups. However, from the second week onwards, there were differences between samples. At week 2, the average height of plants grown under LEDs was highest at 3.43 cm, followed by the incandescent lights (ILs) (3.15 cm) and finally compact florescent 3U lights (CFLs) (2.93 cm). By the week 8th (in the flowering stage), the plants grown under LED continued to lead in height, while plants grown under CFLs was in second place. As a result, before harvesting (in the last week), LED lighting plants were 2-4cm higher than plants utilizing CFLs or ILs although the lamps were only turned on within the first month and then stopped. This proves that LED lighting at nighttime in the first month will

facilitate the growth of *Chrysanthemum* in the following months. Regarding stem diameter, similar to the plant height, the average stem diameter of the LED lighting plants was statistically higher than that of the control lamps starting from the 3rd week. There were only slightly differences between plants grown under CFLs and ILs at the time of harvest.

Table 1: Effect of supplemental night lighting by LED, compact florescent 3U (CFL) and incandescent (IL) lamps to the number of flowering buds and the number of qualified plants for harvesting.

	LEDs		CFLs		ILs	
	Plants	%	Plants	%	Plants	%
Total number of plants	1416	100%	1231	100%	1217	100%
Total number of plants having flower(s)	1274	90%	1083	88%	1059	87%
Total number of qualified plants	1062	75%	850	69%	780	64%

Table 2: Effect of supplemental night lighting by LED, compact florescent 3U (CFL) and incandescent (IL) lamps to plant height and stem diameter of the *Chrysanthemum*.

Week	Plant height (cm)				Stem diameter (cm)			
	LEDs	CFLs	ILs	LSD	LEDs	CFLs	ILs	LSD
0	2,02^{a}	1,95^{a}	1,93^{a}	*0,195*	0,89^{a}	0,89^{a}	0,88^{a}	*0,019*
1	2,77^{a}	2,56^{a}	2,93^{a}	*0,226*	0,95^{a}	0,95^{a}	0,97^{a}	*0,027*
2	3,43^{a}	2,93^{b}	3,15^{c}	*0,196*	1,36^{a}	1,29^{a}	1,31^{a}	*0,081*
3	4,16^{a}	3,55^{b}	3,83^{c}	*0,145*	1,71^{a}	1,54^{b}	1,60^{b}	*0,078*
4	4,85^{a}	4,31^{b}	4,59^{c}	*0,085*	2,02^{a}	1,87^{b}	1,98^{a}	*0,056*
5	5,61^{a}	5,04^{b}	5,34^{c}	*0,100*	2,43^{a}	2,21^{b}	2,31^{b}	*0,151*
6	6,87^{a}	6,18^{b}	6,63^{c}	*0,133*	2,69^{a}	2,49^{b}	2,55^{b}	*0,162*
7	8,89^{a}	7,75^{b}	8,09^{c}	*0,157*	2,98^{a}	2,63^{b}	2,73^{b}	*0,213*
8	11,48^{a}	9,88^{b}	10,04^{b}	*0,192*	3,21^{a}	2,87^{b}	2,88^{b}	*0,221*
9	14,32^{a}	12,65^{b}	12,53^{b}	*0,276*	3,49^{a}	2,97^{b}	3,03^{b}	*0,312*
10	17,65^{a}	15,64^{b}	15,60^{b}	*0,294*	3,58^{a}	3,09^{b}	3,19^{b}	*0,293*
11	20,90^{a}	18,70^{b}	18,35^{c}	*0,267*	3,74^{a}	3,23^{b}	3,30^{b}	*0,341*
12	24,50^{a}	21,73^{b}	21,13^{c}	*0,440*	3,98^{a}	3,44^{b}	3,57^{c}	*0,272*

Letters a, b, c represent statistically significant differences between variables in different light systems ($P<0.05$).

After planting for 4 weeks, all plants had slow leaf initiation rates and small leaf size (Table 3). Weather conditions did affect the development of the leaves in the early stage since there was heavy rain during this period. Lighting systems did not exhibit clear effects towards *Chrysanthemum* leaves of young plants. In the second and the third month, the plants started to show differences between those grown under different light sources. Overall, LED lighting help increasing the number and the size of leaves in compared to other techniques.

Table 3: Effect of supplemental night lighting by LED, compact florescent 3U (CFL) and incandescent (IL) lamps to leaf quantity, leaf blade length and width of the *Chrysanthemum*.

Week	Number of leaves/plant				Leaf blade length (cm)				Leaf bladewidth (cm)			
	LEDs	CFLs	ILs	LSD	LEDs	CFLs	ILs	LSD	LEDs	CFLs	ILs	LSD
0	3,93 ^{a}	3,83^{a}	3,87^{a}	*0,476*	2,60^{a}	2,56^{a}	2,61^{a}	0,137	2,09^{a}	2,14^{a}	2,13^{a}	*0,136*
1	6,25 ^{a}	5,95^{a}	6,05^{a}	*0,626*	3,15^{a}	3,06^{a}	3,08^{a}	0,101	2,49^{a}	2,39^{b}	2,38^{b}	*0,040*
2	8,28^{a}	7,90^{ab}	7,72^{b}	*4,427*	3,38^{a}	3,27^{b}	3,30^{ab}	0,082	2,70^{a}	2,56^{b}	2,54^{b}	*0,069*
3	9,70^{a}	9,27^{b}	9,07^{b}	*0,252*	3,59^{a}	3,47^{b}	3,53^{c}	0,050	2,90^{a}	2,73^{b}	2,74^{b}	*0,063*
4	10,87^{a}	10,35^{b}	10,20^{b}	*0,309*	3,83^{a}	3,67^{b}	3,73^{c}	0,066	3,07^{a}	2,87^{c}	2,95^{b}	*0,065*
5	12,35^{a}	11,47^{b}	11,33^{b}	*0,236*	4,08^{a}	3,86^{b}	3,99^{a}	0,108	3,36^{a}	3,15^{b}	3,20^{b}	*0,101*
6	15,13^{a}	13,37^{b}	12,95^{c}	*0,327*	4,41^{a}	4,22^{b}	4,36^{a}	0,086	3,60^{a}	3,40^{b}	3,48^{b}	*0,093*
7	16,92^{a}	14,37^{b}	13,95^{c}	*0,366*	4,87^{a}	4,72^{b}	4,89^{a}	0,116	4,01^{a}	3,63^{b}	3,71^{b}	*0,092*
8	19,40^{a}	15,78^{b}	15,68^{b}	*0,455*	5,34^{a}	5,20^{b}	5,43^{a}	0,118	4,29^{a}	3,84^{b}	3,93^{b}	*0,124*
9	21,95^{a}	17,82^{b}	17,20^{c}	*0,100*	5,84^{a}	5,59^{b}	5,91^{a}	0,071	4,48^{a}	4,03^{b}	4,14^{b}	*0,133*
10	24,87^{a}	19,52^{b}	18,93^{c}	*0,394*	6,26^{a}	5,89^{b}	6,29^{a}	0,065	4,62^{a}	4,21^{b}	4,34^{b}	*0,128*
11	26,88^{a}	21,97^{b}	21,32^{c}	*0,366*	6,65^{a}	6,22^{c}	6,57^{b}	0,059	4,78^{a}	4,43^{b}	4,53^{b}	*0,134*
12	28,03^{a}	23,58^{b}	22,87^{c}	*0,543*	6,91^{a}	6,51^{b}	6,83^{a}	0,092	4,93^{a}	4,57^{b}	4,69^{b}	*0,126*

Letters a, b, c represent statistically significant differences between variables in different light systems ($P<0.05$).

Influences of different lighting sources to flower-related parameters were showed in table 4 and 5. The number of flowers is a useful indicator of flower product quality and decides the price of the products. At any time, the number of flowers per plants grown under LEDs was larger than others (Table 4). Prior to harvest, the number of flowers per plant in the LED system was over 22, whereas it was less than 19 in other light sources. LED lighting plants emerged flower buds earlier from 5 to 7 days than plants grown under compact and incandescent lights (Table 5). Despite of that, the flowers still larger in size for plants grown under LEDs in comparison with CFLs and ILs.

Table 4: Effect of supplemental night lighting by LEDs, compact florescent 3U (CFLs) and incandescent (ILs) lamps to the mean flower number per plant.

Week	Flower number/plants			LSD
	LEDs	CFLs	ILs	
9	7,05^{a}	5,32^{c}	6,30^{b}	*0,637*
10	12,72^{a}	8,83^{b}	8,87^{b}	*1,355*
11	17,88^{a}	14,52^{b}	14,75^{b}	*1,211*
12	22,22^{a}	18,62^{b}	18,77^{b}	*1,163*

Letters a, b, c present the level of statistically significant differences between variables in different light systems ($P<0.05$).

Table 5: Effect of supplemental night lighting by LEDs, compact florescent 3U (CFLs) and incandescent (ILs) lamps to the first emerging date of flower bud, and the average diameter of the main flowers.

Flower related parameters	LEDs	CFLs	ILs
First emerging date of flower bud	52	59	57
Diameter of the main flowers (cm)	6.63^{a}	5.70^{b}	5.86^{b}

Letters a, b, c represent statistically significant differences ($P<0.05$).

Discussion

The effects of supplemental lighting towards plant growths were largely investigated in *in-vitro* and greenhouse conditions. Previous results have proved the benefits of this technique in agriculture productions[3], [4], [6], [8], [9]. According to N.B. Nam et al. (2014) the differences in the heights of Doa Vang (other name of Pha Le) *Chrysanthemum* grown in the greenhouse under diffrent supplemental light sources including LEDs and compact light were not apparent in the first 4 weeks but became more obvious in the following periods [8]. Also, in this report, the authors concluded that there was an increasing in stem diameter, leaf length, leaf width and flower diameter in plants grown under LEDs, compared to those grown under compact lamps. These statements are in agreement with our findings.In our study, the open-field conditions are substantially different from controlled conditions in laboratory or in greenhouse. Continuous changes in temperature, humidity, wind speed, etcon the fields add to plant abiotic stresses, henceexhibite plant growths. These environmental factors also have impacts on plant development, especiallyon flowering initiation stage [1], [2], [7]. Our research shows that the LED lightings had positive effects towards plants even under natural environment at the field. LED lightings increased plant height and leaf size in open-field conditions, just as in greenhouse [9]. However, it is hard to compare the level of inffluence of supplemental LED lighting between two conditions since polyhouse conditions are superior than open-field conditions for growing *Chrysanthemum* in some studied parameters even without supplemental lighting [10].

Conclusions

LED supplemental lighting at night with suitable light spectrum stimulated the growth of the Chrysanthemum in the early stage, thus enhanced plant development at reproducing stage. Compared to compact florescent and incandescent lighting, flower plants grown under LEDs was bloomed earlier yet got higher quality in term of plant height, stem, leaf and flower sizes as well as leaf and flower numbers.

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