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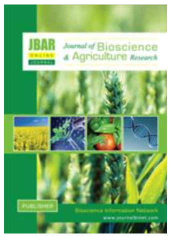

Influence of supplement LED spectrum on growth and yield of Strawberry

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ABSTRACT

A field experiment was performed during winter season from December 2015 to March 2016 at the Horticulture farm, Department of Horticulture of Sher-e-Bangla Agricultural University, Dhaka to investigate the influence of different supplemental LED spectrum on growth and yield of Strawberry. Five treatments viz. Control (L_0), White LED light (L_W), Blue LED Light (L_B), Red LED Light (L_R) and Combined Red and Blue LED light (L_{R+B}); were used in this experiment arranged in randomized complete block design (RCBD) with. L_B treatment showed best performance regarding vegetative growth (plant height 33.7 cm, leaf area 88.8 cm^2, No. of leaf/plant 25.3, No. runner/plant 6.0 and No. of stolon/plant 5.0) whereas L_R showed best in reproductive growth (Days to first flower bud, flowering, fruit setting and harvesting 52.0, 54.0, 67.3 and 101.3 days respectively). L_{R+B} treatment showed statistical similarity to the best in all the parameters and gave the highest yield (yield/plant and yield/ha 475.3 g and 16.6 ton respectively). So, a combined supplementation of red and blue LED light can be recommended to boost the quality and production of strawberry.

Key Words: *Strawberry, Light emitting diode, Spectrum and Yield*

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I. Introduction

Light plays a major role in the life cycle of a plant regulating their photo-morphogenesis and photosynthesis (Avercheva *et al.*, 2009). Studies over the last several decades, primarily on *Arabidopsis thalania* have showed that variation in light quantity, quality and photoperiod can be manipulated to affect growth and control developmental transitions (Folta *et al.*, 2005). Basic plant research with different spectrum of light demonstrated that specific light wavelengths may affect plant physiology such as germination, stem growth (Parks *et al.*, 2001), biomass and transition to flowering (Valverde *et al.*, 2004). In recent days, LED lights are gaining rapid popularity as a source of artificial light over the others due to some unique advantages like spectral composition control, light weight,

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long lifetime, low energy composition, specific wavelength and relatively cool light. These solid-state light sources are therefore ideal for use in plant lighting designs, and they allow wavelengths to be matched to plant photoreceptors to provide more-optimal production, and influence plant morphology and metabolism (Bourget, 2008; Massa *et al.*, 2008; Morrow, 2008). Past studies also prove the importance of blue and red spectrum ranges (Cosgrove 1981; Kasajima *et al.*, 2008). Combined Red and Blue LED lights were proven to be an effective lighting source for producing many plant species (Brown *et al.*, 1995; Yanagi *et al.*, 1996; Tanaka *et al.*, 1998; Yorio *et al.*, 2001; Hanyu and Shoji, 2002; Lian *et al.*, 2002; Nhut *et al.*, 2003; Dougher and Bugbee, 2004; Lee *et al.*, 2007; Shin *et al.*, 2008). Strawberries (*Fragaria X ananassa Duch*.) are widely appreciated for their excellent taste, characteristic aroma, and bright red color causing its production to be twice the amount of all other berry crops combined (Stewart, 2011). They are an excellent source of vitamin C, and are also rich in bioactive phenolic compounds including flavonoids and phenolic acids, such as hydroxycinnamic acids, ellagic acids, ellagitannins, xavan-3-ols, xavonols, and anthocyanins (Tulipani *et al.*, 2008). Strawberries have been shown to have a remarkably high scavenging activity toward chemically generated radicals, thus making them effective in inhibiting oxidation of human LDLs (Heinonen *et al.*, 1998). The antioxidant activity of strawberries could contribute to the prevention of cancer, cardiovascular and other chronic diseases (Hannum, 2004). It is a new fruit crop that has the potential of becoming a money spinning cash crop. Although we have sufficient light during winter to produce strawberry, supplementing with specific spectra of light using LED might let us get the production to achieve the objective. With this view in mind, the present research was conducted to evaluate the growth and yield of strawberry under supplement LED light.

II. Materials and Methods

The experiment was conducted in "Nandini 2" net house in Horticulture Farm, Sher-e-Bangla Agricultural University during the period of December, 2015 to March, 2016. Plantlets of the strawberry cultivar (Festival) have been collected from the tissue culture laboratory, BRAC and used in this experiment under five LED light supplementation treatment which were L_C= Control (No LED supplementation), L_W= White LED, L_B= Blue LED, L_R= Red LED and L_{R+B}= Both Red & Blue LED. The experiment was set in a Randomized Complete Blocked Design in 3mX1m plots with three replications. The light extension was done for three hours from the onset of dusk. Data on plant height (cm), number of leaves/plant, Leaf area (cm^2), number of runner/plant, number of stolon/plant, days to first flower bud, days to first flowering, days to first fruit setting, days to first fruit harvesting, number of fruit/plant, weight of single fruit (g), fruit length (cm), fruit diameter (mm), yield/plant (g), yield/ha (t) were collected for growth and yield evaluation. All the collected data were arranged accordingly and statistical analysis was conducted using MSTAT-C computer program with Least Significant Difference (LSD) among the different treatments evaluated at 5% level of probability (Gomez and Gomez, 1984).

III. Results and Discussion

Plant height

Different colors of LED spectrum showed significant impact on plant height of strawberry. The tallest strawberry plant (33.7 cm) was attained from plants under blue light to which red and blue light combination showed statistical similarity (33.3cm) whereas the shortest plant (25.3 cm) was recorded from control treatment (Figure 01). This finding show similarity to that of Zheng *et al.* (2016) and Uddin *et al.* (2017). Naznin *et al.* (2016) also found that ratios of red to blue LEDs showed higher plant height in strawberry. Similar experiments on plant height by different LED spectrum were done by many photobiologists such as Park and Runkle (2016) on snapdragon (*Antirrhinum majus*); Tarakanov *et al.* (2012) on Sweet pepper (*Capsicum annuum L.*); and Guo *et al.* (2016) on mini-cucumber.

Number of leaf

Number of leaves expressed significant inequality in strawberry plants grown under different LED spectrums. Plants under blue LED light showed maximum number of leaves (25.3) whereas the minimum (18.0) was found in control treatment (Figure 01). He *et al.*, (2016) have shown same findings that supplement LED light increase number of leaf in lettuce (Lactuca *sativa*). Uddin *et al.* (2017) also found similar result in case of broccoli plants.

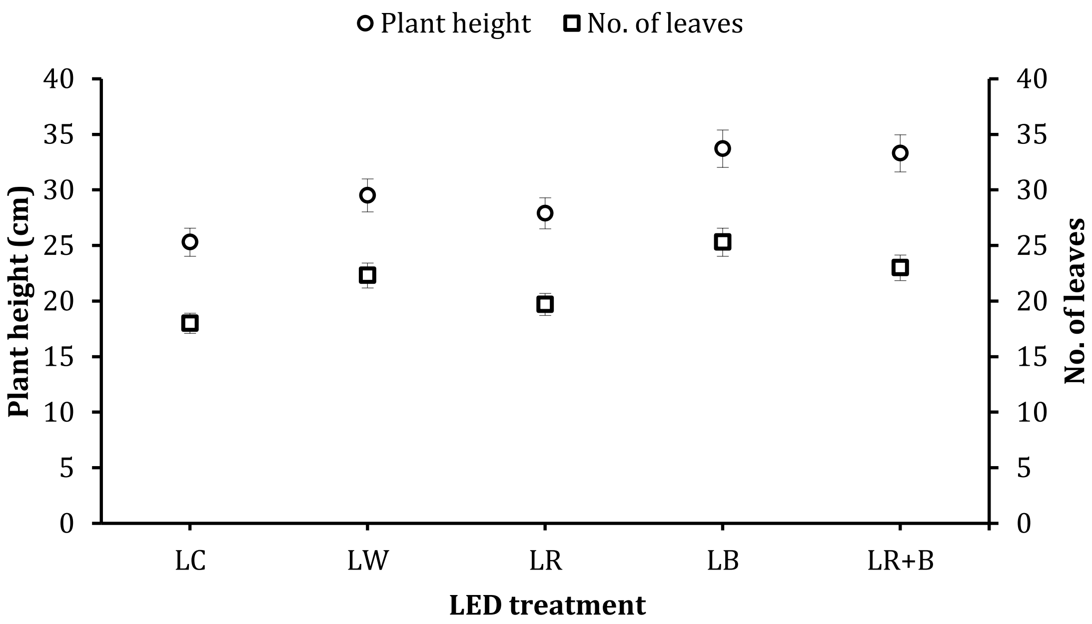

Figure 01. Different LED spectrum influence on plant height and no. of leaves of strawberry.
*Here, L_C= Control, L_W= White LED, L_R= Red LED, L_B= Blue LED and L_{R+B}= Red+Blue LED

Leaf area
Significant variation in case of leaf area was observed in strawberry plants under different LED spectrums. Maximum leaf area (88.8 cm^2) was found from blue LED treatment to which red and blue LED combination showed statistical similarity (88 cm^2) whereas the minimum (72.4 cm^2) was found in control (Table 01). Similar experiments on leaf area by different LED spectrum were done by many photobiologists such as Wu *et al.,* (2007) on pea seedlings; Van Delm *et al.,* (2016) on strawberry; He *et al.,* (2016) on *Lactuca sativa*; Hernández *et al.* (2016) on different vegetable seedlings like tomato and cucumber; Novičkovas *et al.* (2012) on cucumber; Stutte *et al.,* (2009) on lettuce (*Lactuca sativa* L.).

Number of runner
Number of runner showed significant difference when treated with different LED light treatments. The highest number of runner (6.0) was obtained from blue light treatment and the minimum (2.8) was found in control treatment (Table 01). The results are in conformity with the findings of Samuolienė *et al.* (2010) and Naznin *et al.* (2016).

Number of stolon
Significant variation was also found among the LED spectrum treatments in terms of stolon number. Blue LED light treatment showed highest number of stolon (5.0) whereas red LED light showed the lowest (1.9) (Table 01)

Days to first flower bud
Significant variation was found among the plants under different LED spectrum in respect to days to first flower bud from days after transplantation of strawberry plantlets. Flower bud became visible earliest in red LED treatment (52.0 days) and control exhibited the latest (62.3days) (Table 01). Hidaka *et al.* (2016) have shown 12-h photoperiod treatment showed a significant increase in leaf photosynthesis and earlier differentiation of flower buds on strawberry plant. Samuolienė *et al.,* (2010) also showed that red LED induced elongation of flowering stem the frigo plants of 'Elkat'strawberries (Fragaria x *ananassa* Duch).

Days to first flower
Different level of treatments with LED lights had significant effect on the emergence of flowering in strawberry. Maximum days required (64.3 days) for the emergence of first flower was found in control

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treatment and the minimum days required for the first visible flowering (54 days) was recorded in red LED light treatment (Table 01). The findings were in conformity to that of Hidaka *et al.* (2016) in strawberry and Fukuda *et al.* (2016) in petunia.

Days to first fruit

Significant variation was observed in case of days to first fruiting of strawberry plants grown under different LED spectrum. Early fruiting (67.3 days) was recorded in red LED treated plant and delayed (73.0 days) in blue LED (Table 01). Early flower initiation leads to an early fruiting, which may reduce the total time needed for crop production, ultimately leads to a higher cropping intensity. Van Delm *et al.*, (2016) have shown in strawberry which under LED assimilation light caused an earlier yield; i.e. earlier flower bud initiation, flower emergence and fruit setting.

Days to first fruit harvest

Significant variation was found on days to first fruit harvesting with different LED spectrum treatment. Longest period (109.7 days) required for harvesting fruit was found under blue LED treatment whereas shortest period (101.3 days) was observed in red LED treatment (Table 01). Similar findings were expressed by Hao *et al.* (2016) in case of tomato.

Table 01. Influence of different LED spectrums on vegetative, flowering and fruiting parameters of strawberry

Treatment	Leaf area (cm^2)		No. of runner		No. of stolon		Days to first flower bud		Days to first flower		Days to first fruit		Days to first fruit harvest	
L_C	72.4	d	2.8	d	2.7	c	62.3	a	64.3	a	71.0	b	106.7	b
L_W	82.8	b	4.3	bc	3.7	b	60.3	ab	62.3	ab	70.3	b	105.7	bc
L_R	77.6	c	3.7	c	1.9	d	52.0	d	54.0	d	67.3	c	101.3	d
L_B	88.8	a	6.0	a	5.0	a	57.7	bc	59.7	bc	73.0	a	109.7	a
L_{R+B}	88.0	a	4.7	b	4.0	b	56.3	c	58.3	c	68.7	c	103.3	cd
CV %	*1.1*		*8.7*		*8.7*		*2.8*		*2.7*		*1.1*		*1.2*	
LSD (0.05)	*1.6*		*0.7*		*0.6*		*3.0*		*3.0*		*1.5*		*2.5*	

*Here, L_C= Control, L_W= White LED, L_R= Red LED, L_B= Blue LED and L_{R+B}= Red+Blue LED

Number of fruit per plant

Number of fruit per plant was significantly influenced by different color LED light treatment where maximum number of fruit (15.7) was recorded under red + blue combined LED light treated plants while the minimum (9.3) were obtained under blue LED light (Table 02). Hidaka *et al.* (2016) have shown incorporating supplemental light increased in flower number and shortening of the fruit maturation period caused by a significant increase in harvested fruit number and yield. The results are in conformity with the findings of Gómez and Mitchell (2016) on using LEDs for high-wire greenhouse tomato.

Weight of single fruit (g)

Significant variation was observed for single fruit weight with different treatments of LED spectrum. Highest fruit weight (30.3 g) was found in red LED treatment whereas lowest (23.0 g) was found from blue LED treatment (Table 02). Hidaka *et al.* (2013) examined the supplement LED light which lead to significant increases in average fruit weight of strawberry. Jiheng *et al.* (2013) have shown similar type of experiment on cucumber.

Length of fruit

Significant inequality was found among the LED light treatments in case of fruit length of strawberry. Maximum fruit length (43.7 mm) was found in red LED and the minimum fruit length (31.8 mm) was given by control (Table 02).

Diameter of fruit

Fruit diameter of strawberry varied significantly under different LED spectrum treatments with the maximum fruit diameter (36.4 mm) observed in red and blue combination treatment and the minimum (25.3 mm) observed in control (Table 02). Samuolienė *et al.* (2010) has found in the frigo plants of 'Elkat' strawberries (*Fragaria* x *ananassa* Duch.) that red and blue LED spectral components is necessary for the development of frigo strawberries which results in bigger size of fruits formed. This may be due to the translocation of large amount of carbohydrate produced in leaf to fruit under LED irradiance (Hidaka *et al.*, 2016).

Yield per plant

Yield per plant also expressed significant inequality under different LED spectrum treatments in case strawberry. Plants treated with red and blue combination treatment gave highest total (475.3 g/plant) yield whereas lowest total (215 g/plant) came from control fruit weight (Table 02). The results are in conformity with the findings of Hidaka *et al.*, (2013) who found that LED supplemental lighting accelerated photosynthesis promoted plant growth, as manifested by increases in leaf dry matter production, leaf area, and specific leaf weight, leading in turn to significant increases in average fruit weight, number of fruits and marketable yield.

Yield per ha

Significant variation was also found among the supplement LED treated strawberry plants in case of yield/ha. The highest fruit yield/ha (16.6 t) was obtained from red and blue light combined treatments; while the lowest fruit yield /ha (7.5t) was found in the blue LED treatment (Table 02). The result is in conformity with that of Hidaka *et al.*, (2013) who observed higher yields in LEDs exposed strawberry plants compared with those under fluorescent lamp illumination which may be due to comparatively higher light intensities. Similar results were also found by Guo *et al.* (2016); Kumar *et al.* (2016) in mini cucumber and Gómez and Mitchell (2016) in tomato.

Table 02. Influence of different LED spectrums on yield parameters of strawberry

Treatment	No of fruit/plant	Weight of single fruit (g)	Length of fruit (mm)	Diameter of fruit (mm)	Yield/plant (g)	Yield/ha (t)
L_C	11.3 b	27.1 b	31.8 e	25.3 c	306.8 c	10.7 c
L_W	11.7 b	27.6 b	36.8 c	29.0 b	321.6 c	11.3 c
L_R	14.7 a	30.3 a	42.0 a	35.8 a	426.8 b	14.9 b
L_B	9.3 c	23.0 c	36.0 d	28.8 b	215.0 d	7.5 d
L_{R+B}	15.7 a	29.1 a	40.3 b	36.4 a	475.3 a	16.6 a
CV %	*4.4*	*2.7*	*1.0*	*1.5*	*5.0*	*4.98*
LSD (0.05)	*1.0*	*1.4*	*0.7*	*0.9*	*32.8*	*1.15*

*Here, L_C= Control, L_W= White LED, L_R= Red LED, L_B= Blue LED and L_{R+B}= Red+Blue LED

IV. Conclusion

Based on the findings of the experiment, it can be concluded that supplement lighting with combined red and blue LED light can be a viable practice to improve the quality and production of strawberry plants grown in Bangladesh.

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