Effect of Light-Emitting Diodes on Different Growth Stages of Rice

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Abstract

Effect of red and blue light on seed germination and seedling growth were studied in rice (*Oryza sativa* L.). Rice seeds were germinated in dark (control) and two types of light emitting-diodes (LED): red and green in the laboratory. The photoperiod of 6 h light and 18 h dark for LEDs treatment and 24h dark treatments with 24/18 ± 2 °C day/night temperature and 78± 2 % relative humidity were maintained in the growth room. Seed germination percentage under red light increased significantly when compared with the control; however in blue light, germination percent decreased with little difference. First leaf length, first leaf blade length, root length, seedling fresh and dry weight increased under red and blue lights in most of the varieties. Highest germination (98%), longest root (8.18 cm) and high seedling fresh weight (0.527 g) and seedling dry weight (0.061g) in BRRIdhan71 and longest leaf in BRRIdhan75, were recorded under red light. Highest germination (96%), seedling fresh weight (0.414g) and seedling dry weight (0.047g) in BRRIdhan71, longest first leaf (6.50 cm) in BRRIdhan75 and longest root (9.37 cm) in BRRIdhan87 were recorded under blue light. First leaf blade showed only positive correlation with root length (r = 0.489), whereas seedling fresh weight showed complete correlation with seedling dry weight (r =1). Response index was positive in root length, seedling fresh and dry weight under red light. First leaf blade length, seedling fresh and dry weight had the positive response index under blue light. Within the visible spectrum, varying wave lengths of red and blue light alone altered the growth and morphology of rice seedlings, and variable reactions to illumination depended on the rice varieties, necessitating further research.

Key words: Growth stage, Light-emitting diode, Rice, Response index.

Introduction

Light is regarded to be one of the most essential internal and environmental variables influencing seed germination and seedling growth (Griffith and Link, 1957). Germination, growth, and differentiation of plant and seed, all are affected by light intensity and quality (Ichihashi, 1982; Economou and Read 1987).

Growth of plant cells and organs, morphological, anatomical and physiological characteristics, photosynthetic features and yield of crops are influenced by different light wave lengths (Deng *et al.,* 2007; Li, 2010). Plant responses such as leaf photosynthetic process, phototropism, photo-morphogenesis, and stomatal function are all influenced by blue light. High photosynthetic capacity of chloroplasts, has been linked to blue light (Kopsell and Sams, 2013).

Effects of blue light on the leaf or whole-plant level have been compared regarding the responses to a white light source with responses to blue-deficient light (Matsuda *et al.,* 2008), or compared the plants treated with blue or a combination of red and blue lights with plants treated with red light alone. In general, blue light containing irradiance causes higher biomass production and photosynthetic capacity. Red (R) and blue (B) lights have the greatest impact on plant growth because they are the major energy sources for photosynthetic CO_2 assimilation in plants. It is well known that spectra have action maxima in the B and R ranges (Kasajima *et al.,* 2008).

LED lights emits specific wavelengths and a narrow bandwidth when compared with filters with broad-spectrum light sources, which could be good for plant growth. As a result, blue and red LED lights can more efficiently produce the specified blue or red spectrum than blue or red filters with other light sources. Before the adoption of light-emitting diodes (LEDs) that were intense enough for experimental planting, light sources in a wider spectrum than red (600 to 700 nm) or blue (400 to 500 nm) were utilized (Kilic *et al.,* 2010).

LEDs that combine red and blue light have a stronger effect on photosynthetic properties than blue-deficient light produced by a filter (Matsuda *et al.,* 2007; 2008). As a result, it must be explored whether plants exposed to only red or blue light suffer from a spectral deficiency syndrome that can be alleviated by using additional light sources with longer wavelengths or combination of short and longer wave lengths. Artificial light environments have a positive and negative impact on rice morphology, physiology, and yield (Chen *et al.,* 2014; Zhang *et al.,* 2016; Xu *et al.,* 2020; Duan *et al.,* 2020), but there is little evidence on the usage of red or blue LEDs alone in rice seed germination and seedling growth.

In this study, the effects of different light spectra such as red and blue LED lights were determined on seed germination and growth parameters, of rice (*Oryza sativa* L.) as a model plant.

Materials and Method

Seed material and germination tests

Rice seeds of BRRIdhan67, BRRIdhan71, BRRIdhan75 and BRRIdhan87 (Table 1) were collected from the Bangladesh Rice Research Institute, Regional station Gopalganj. The laboratory studies were conducted in the laboratory of Department of Agriculture, Bangabandhu Sheikh Mujibur Rahman Science and Technology University and Laboratory of Bangladesh Rice Research Institute, regional station Gopalganj.

Table 1. Description of the four rice variety used in the present study

Rice variety	Growing season	Special phenotypic feature	Year of Release, Institution
BRRIdhan67	Boro	Salinity tolerant	2014, BRRI
BRRIdhan71	Aman	Drought tolerant	2014, BRRI
BRRIdhan75	Aman	Uptakes 25% less nutrient	2014, BRRI
BRRIdhan87	Aman	Soma-clonal variant	2016, BRRI

Light source and treatments

For the dark treatment of rice seeds, the petriplates were covered with black cotton cloth. Light treatment of the rice seed with petriplates were kept under illumination using a cool, red and blue light emitting diode source with 6 h light and 18 h dark period. Seeds were incubated at 22 ± 2 °C and relative humidity of 78± 2 % during the incubation period. Specification of the 12W red and blue LED light: Voltage range 85 – 265 V; Frequency 50 – 60Hz; power factor ≥ 0.5; efficacy ≥ 95lm/W; color rendering index ≥ 80%; total harmonic distribution ≤ 15%; high lumen PF>0.9; 6500k daylight, ambient temperature: -20 C ~40 C . Distance between red and blue LED light and seed or seedling were adjusted to get the approximately equal photosynthetic photon flux (PPF). The plants without red and blue light were used as the control.

The germination test was conducted using the petridish method with three replicates of 100 seeds. Seeds were soaked in distilled water for 36 h at room temperature and placed on Whatman filter paper no.1. The Petri dishes were observed every day and the numbers of germinated seeds were recorded at 24 h interval up to 14 days from set up of the test.

Data collection

Germination

Germination was recorded daily and was considered complete once the radicle protruded about 2 mm in length. The experiments were continued for 14 days (Ellis and Roberts, 1981).

Germination per cent

A seed was considered to be germinated as seed coat ruptured, plumule and radicle came out and were >2mm long. Germination count was expressed in percentage. The germination percentage was calculated using the following formula (International Seed Testing Association, 2006).

Germination (%) = (Number of seed germinated/Total number of seed for test) × 100

Measurement of leaf, root and shoot length

Randomly selected five seedlings were taken from each petridish to measure first leaf length, first leaf blade length, root length and shoot length. Data were measured with a measuring scale and expressed in centimeters. First leaf length, first leaf blade length, root length and shoot length of the seedlings were measured after 17 days of seed setting for germination (Kouio, 2003).

Measurement of fresh weight and dry weight of the seedling

After 17 days of seed setting 15 seedlings of each petridish were wrapped with brown paper and weighed the fresh weight first and then they were died in oven at 70° C for 48 hours and weighed the dry weight. These were measured by four digit balance and expressed in gram.

Response index

Response index (RI) was calculated to know about inhibition and stimulation by different lights on seed germination and seedling growth (Tehrani *et al.*, 2016)
RI was calculated as: RI = (T/C - 1) × 100, where, T is the parameter under treatment and C is the parameter under control.

Data analysis

All measurements were evaluated for significance using analysis of variance (ANOVA) followed by the least significant difference (LSD) test at the $P < 0.05$ level. Completely Randomized Design was used to test the variation in rice varieties and growth condition. Simple linear correlation coefficient were calculated to find out the interrelation of the studied characters. All statistical analyses were conducted using MSTAT-C (Statistical analysis software) computer package program (Gomez and Gomez, 1984).

Result and Discussion

All of the studied parameters, including germination percent, first leaf length, first leaf blade length, root length, seedling fresh weight, and seedling dry weight, for four rice varieties: BRRIdhan67, BRRIdhan71, BRRIdhan75 and BRRIdhan87 are presented in Table 2.

Table 2. Rice seed germination and seedling morphology as affected by dark and lighting from red and blue light-emitting diodes (LEDs)

Variety	Germination (%)	First leaf length (cm)	First leaf blade length (cm)	Root length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)
Dark						
BRRIdhan67	96 ±1.15	10.18 ±0.24	2.48 ±0.06	4.10 ±0.18	0.305 ±0.009	0.035 ±0.001
BRRIdhan71	99 ±0.58	8.43 ±0.34	2.22 ±0.04	6.69 ±0.19	0.405 ±0.008	0.047 ±0.003
BRRIdhan75	70 ±1.15	8.46 ±0.15	1.93 ±0.03	4.94 ±0.15	0.304 ±0.008	0.035 ±0.001
BRRIdhan87	78 ±1.12	10.17 ±0.21	2.90 ±0.07	5.63 ±0.10	0.297 ±0.002	0.034 ±0.004
Red LEDs						
BRRIdhan67	96 ±1.15	5.03 ±0.034	2.41 ±0.079	6.48 ±0.10	0.422 ±0.010	0.049 ±0.0015
BRRIdhan71	98 ±0.33	4.97 ±0.034	2.47 ±0.001	8.18 ±0.18	0.527 ±0.001	0.061 ±0.00015
BRRIdhan75	84 ±1.15	7.06 ±0.167	2.38 ±0.030	5.10 ±0.38	0.350 ±0.011	0.040± 0.0013
BRRIdhan87	82 ±4.16	6.72 ±0.101	2.74 ±0.088	5.81 ±0.17	0.332 ±0.010	0.038 ±0.0012
Blue LEDs						
BRRIdhan67	92 ±1.73	4.94 ±0.14	2.46 ±0.04	6.69 ±0.12	0.312 ±0.002	0.036 ±0.001
BRRIdhan71	96 ±1.73	4.86 ±0.03	2.28 ±0.02	6.68 ±0.35	0.414 ±0.019	0.047 ±0.003
BRRIdhan75	78 ±1.15	6.50 ±0.09	2.46 ±0.05	4.85 ±0.09	0.330 ±0.001	0.038 ±0.0011
BRRIdhan87	89 ±1.53	5.95 ±0.09	2.63 ±0.06	9.37 ±0.09	0.373 ±0.005	0.043 ±0.0013

Values show Mean ± SE (n=5). All the values were significantly different at $p \leq 0.0001$.

Germination

In dark seed germination ranged from 70 to 99 percent. Highest germination was recorded in BRRIDhan71 and lowest in BRRIdhan75. Germination percent ranged from 82 to 98 with highest in BRRIdhan71 and lowest in BRRIDhan87 under red light (Plate 1). Whereas germination percent ranged from 78 to 96 under blue light. Highest germination was recorded in BRRIdhan71 and lowest in BRRIdhan75. The result of the study show that, red and blue light increases the germination percentage (Table 2). Earlier investigations showed that light spectrum plays an important role in germination and seedling growth. Many studies have revealed that different plant species had optimal growth and development in response to the light they received (Li *et al.,* 2012). Tang *et al.* (2010) showed that seed germination of some plants occurred under different light spectra. Tang (2008, 2010) reported that seed germination of some important weeds, among them *Chenopodium album* L. increased when treated with red light. Different rice varieties, different growth stages, and light environment have different effects on rice growth status and quality (Xu *et al.,* 2020).

(a) Seedlings of BRRIdhan71 grown under red light

(b) Seedlings of BRRIdhan71 under blue light

Plate 1. Effect of red (a) and blue light (b) on germinated seedling of BRRIdhan71.

Seedling characters

First leaf length ranged 8.43 to 10.18 cm in dark. Longest leaf was found in BRRIdhan67 and shortest leaf in BRRIdhan71. Under red light first leaf length ranged from 4.97 to 7.06 cm. Seedling grown under blue light, first leaf length ranged from 4.86 to 6.50 cm. BRRIdhan75 had the longest and BRRIdhan71 had the shortest first leaf under red and blue light. In present study blue light inhibited leaf length more than the red light, which agree with the findings of Chen *et al.* (2014), stated that blue light inhibited shoot elongation. Different wave lengths mediated the chlorophyll a and chlorophyll b ratio of the leaves.

First leaf blade length ranged from 1.93 to 2.90 cm in dark. Highest leaf blade length was found in BRRIdhan87 and lowest in BRRIdhan75. Under red light first leaf blade length ranged from 2.38 to 2.74. BRRIdhan87 had the highest value and BRRIdhan75 had the lowest. While, first leaf blade length ranged from 2.28 to 2.63 under blue light. Highest leaf blade length was found in BRRIdhan87 and lowest in BRRIdhan71. Results from Table 2 demonstrated that light spectra influenced the seedlings growth of rice and red and blue lights inhibit the leaf and leaf blade length. LED red lights promotes the growth of seedlings (Renliang *et al.,* 2016). Guo *et al.,* (2011) found short seedling length when compared with the control and red light treatments in rice seedlings.

Root length ranged from 4.10 to 6.69 cm in dark. The longest root was found in BRRIdhan71 and shortest in BRRIdhan67. Under red light root length ranged from 5.10 to 8.18 cm. Longest root was found in BRRIdhan71 and shortest in BRRIdhan75. Whereas longest root was found in BRRIdhan87 and shortest in BRRIdhan75 with a range of 4.85 to 9.37 cm under blue light. Liu *et al.* (2011) reported that red to blue ratio affected root morphology and an increase in blue radiation caused longer root length. Guo *et al.* (2011) and Nhut *et al.* (2003) reported that red and blue mixed LEDs were shown to induce root elongation. In the present study root elongation was higher on an average under red and blue light than dark condition.

Seedling fresh weight ranged from 0.297 to 0.405 g in dark. Under red light seedling fresh weight ranged from 0.332 to 0.527 g. Highest seedling fresh weight was found in BRRIdhan71 and lowest in BRRIdhan87 in dark and red light growth condition. Under blue light seedling fresh weight ranged from 0.312 to 0.414 g. BRRIdhan71 had the highest and BRRIdhan67 had the lowest seedling fresh weight. According to Renliang *et al.* (2016), the fresh weight per plant, height and appearance were best under blue light but in the present study seedling fresh weight was higher under red light.

Seedling dry weight in dark, ranged from 0.034 to 0.047 g. Under red light it ranged from 0.038 to 0.061. Seedling dry weight was also found highest in BRRIdhan71 and lowest in BRRIdhan87 in dark and red light growth conditions. Seedling dry weight ranged from 0.036 to 0.047 in blue light. BRRIdhan71 had the highest and BRRIdhan67 had the lowest seedling dry weight. Several studies shows that blue and red mixed LEDs increased biomass (Chen *et al.,* 2014). Shoot biomass could be promoted by the red and blue mixed LEDs.

Table 3. Correlation between seed germination and seedling characters in rice varieties.

	Germination (%)	First leaf length (cm)	First leaf blade length (cm)	Root length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)
Germination (%)	**0**	-0.887*	-0.104*	0.538ns	0.758*	0.764*
First leaf length (cm)		**0**	0.520ns	-0.350*	-0.888*	-0.892*
First leaf blade length (cm)			**0**	0.489*	-0.346*	-0.347*
Root length (cm)				**0**	0.641ns	0.639ns
Seedling fresh weight (g)					**0**	1.00****
Seedling dry weight (g)						**0**

*, **** Indicate significant differences between dark and green LEDs treatment at $p \leq 0.05$ and $p \leq 0.0001$ level, respectively. Ns: Not significant at (n-2) df.

Character association

Correlation was studied for seed germination, first leaf length, first leaf blade length, root length, seedling fresh and seedling dry weight in the four rice varieties (Table 3). Germination percent showed positive and significant correlation with seedlings fresh weight (r = 0.758) and dry weight (r = 0.764). First leaf length showed negative and significant correlation with seedling fresh weight (r = - 0.888) and seedling dry weight (r = - 0.892). First leaf blade length showed positive and significant correlation (r = 0.489) with root length. Complete correlation (r = 1) was observed between seedling fresh weight and seedling dry weight. Correlation of first leaf length with first leaf blade length, germination percent with root length, root length with seedling fresh and seedling dry weight were not significant. Zhang *et al.* (2016) also find positive and significant correlation for shoot and root characters in rice.

Table 4. Response index for growth parameters of 4 rice varieties with red and blue LEDs light and dark (control).

Characters	**Response Index (%)**			
	BRRIdhan67	BRRIdhan71	BRRIdhan75	BRRIdhan87
Red light				
Germination (%)	0.00	-0.34	20.00	5.13
First leaf length (cm)	-50.65	-41.11	-16.54	-33.97
First leaf blade length (cm)	-2.69	10.94	23.28	-5.60
Root length (cm)	58.01	22.14	3.23	3.21
Seedling fresh weight (g)	38.22	30.21	15.22	11.72
Seedling dry weight (g)	38.22	30.21	15.22	11.72
Blue light				
Germination (%)	-4.17	-3.03	11.43	14.10
First leaf length (cm)	-51.45	-42.36	-23.24	-41.53
First leaf blade length (cm)	-0.67	2.62	27.01	-9.39
Root length (cm)	63.02	-0.21	-1.88	66.41
Seedling fresh weight (g)	2.29	2.20	8.41	25.56
Seedling dry weight (g)	1.58	1.24	8.49	25.56

Values in bold letter represent the growth increase and other values indicates growth reduction.

Response index

Response index was calculated to determine the inhibition and stimulation by red and blue lights on seed germination and seedling characters of rice varieties (Table 4), compared with dark condition (control).

Red light stimulated germination percent in BRRIdhan75 (20%) and BRRIdhan87 (5.13%). The germination percentage in BRRIdhan67 was the same as in dark. In BRRIdhan71, germination percentage decreased by 0.34 percent as compared to dark conditions. Blue light hindered germination percent in BRRIdhan67 (-4.17%) and BRRIdhan71 (-3.03). There was increase in BRRIdhan87 (14.10%) and BRRIdhan75 (11.43%).

Red light inhibited first leaf length ranging from -16.54 to -50.65 percent in the rice cultivars studied. In blue light, first leaf length was also decreased in all the rice varieties ranging from -23.24 to -51.45. In comparison to dark, BRRIdhan67 had the highest inhibition while BRRIdhan75 had the lowest.

In the rice cultivars investigated, the first leaf breadth increased significantly. This character received the second most responses compared to the others under red light than dark. BRRIdhan71 had the highest response (23.28), while BRRIdhan71 had the lowest (10.94). Under blue light first leaf breadth increased in BRRIdhan75 (27.01) and BRRIdhan71 (2.62). Negative response was observed in BRRIdhan87 (-9.39) and BRRIdhan67 (-0.67).

Under red light, root length response index ranged from 3.21 to 58.0 compared to dark. The highest response was found in BRRIdhan67, whereas the lowest was found in BRRIdhan67. Blue light influenced the root length of BRRIdhan87 and BRRIdhan67 by 66.41 and 63.02 percent, respectively. Root length inhibition was found in both BRRIdhan75 (-1.88%) and BRRIdhan71 (-0.21).

Seedling fresh and dry weights increased by 11.72 to 38.22 percent in rice varieties. BRRIdhan67 had the highest fresh and dry weight response, whereas BRRIdhan87 had the lowest. Blue light also positively influenced seedling fresh and dry weights ranging from 2.20 to 25.56 and 1.24 to 25.56, respectively. BRRIdhan87 had the highest and BRRIdhan71 had lowest response for seedling fresh and dry weights.

Plant responses to light quality are species or cultivar dependent (Yorio *et al.,* 2001). More studies have shown that the red-blue complex light is superior to the single-quality light treatment for the growth development and the quality of seedlings Renliang *et al.* (2016), but differ with their findings in the present study. Under red and blue LEDs individually most of the rice varieties show different response index positive and negative ways for germination and seedling parameters. Wu Dan *et al*. (2015) and other researchers reported that growing rice seedlings with an increase in the amount of blue light in the light environment and adding short-wave red light can make up for the decrease of rice biomass accumulation. Upon light illumination, elongation of coleoptiles, first leaves and internode is inhibited, and seedling switch to photo-morphogenesis pattern of growth with the development of fully functional chloroplast and transition to autotrophy (Takano, 2005). In the present study effect of red and blue light and response of rice growth stage was notable. Several studies have demonstrated that the addition of small amount of red or blue spectrum can alter plant morphometrics (Saebo *et al.,* 1995).

As a result, the spectral demand of rice is not clearly defined by the light morphogenesis impact, which varies with different types and growth seasons. This necessitates a more in-depth investigation of the changes in the demand for light quality of various rice varieties at various growth stages, as well as the appropriate proportion of combined light, in order to provide a theoretical reference for the more efficient and energy-saving artificial light source application in rice seedling. It also provides a more ecological and scientific theoretical basis for agricultural landscape lighting design. This findings concluded that red and blue light have mostly positive influence on rice seed germination and seedling growth.

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