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Growth of Rice Plant Under Green Light- Inefficient or Neglected

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Abstract

The objectives of this study was to investigate the effect of green light-emitting diodes (LEDs) on rice (*Oryza sativa* L.) seed germination as well as seedling growth. The rice seed of BRRIdhan52, BRRIdhan81, BRRIdhan86 and BRRIdhan92 were germinated and nursed in control environment in full dark (no supplemental light) and under green light (6 h/day with18 h dark). The results showed that germination percent, leaf length, leaf blade length, seedling fresh and dry weight were enhanced by green lighting. Highest germination percent (88%) was counted in BRRIdhan86 and longest first leaf (7.24 cm) with widest leaf (7.24 cm) in BRRIdhan92 under green light. Green light not only enhance the first leaf blade length also increased the dry matter production. High positive significant correlation were observed in seedling fresh weight and dry weight. Correlation value (r) was positive and significantly ranged from 0.999 to 0.981. Green light remarkably promote the leaf surface area, root morphology which ultimately contributed to vigorous seedling growth with an increase 6 to 156 times than rice seedlings grown in dark for the studied character. As a result, the effects of green light emitting diodes (LEDs) on rice seed and seedlings for plant cultivation under controlled-environment conditions are promising, and they may affect subsequent phases of growth and development. More research on green light and other solid state light sources are needed for use in plant lighting designs, as well as the ability to match wavelengths to plant photo sensors for better production and influence on plant morphology and metabolism.

Key words: Correlation, Green light, Growth, Irradiation, Rice

Introduction

Light is the primary source of energy for photosynthesis in plants, as well as an environmental signal that causes them to develop and differentiate structurally. Light, namely the quality and quantity of radiation, is one of the most critical environmental factors for plant growth and development (Folta and Maruhnich, 2007; Jung *et. al.*,2013). The morphogenesis, growth, and differentiation of plant cells, tissues, and organ cultures are influenced by light quality, amount, and photoperiod (Abidi *et al.*, 2013).

Light quality i.e., the colors or wavelengths that reach on a plant's surface, has a significant impact on its development (Jokhan *et al.*, 2010). In the visible wavelength range (380–780 nm), red light (640–660 nm) and blue light (430–450 nm) absorbed most by chlorophylls and other pigments in higher plants, while green light (500–600 nm) least absorbed (Abboud *et al.*, 2013). Green light was therefore assumed to be inefficient for photosynthesis in higher plants when compared to red and blue light (Nishio, 2000).

Green (G) light has been shown to alter plant shape, metabolism, and photosynthesis in recent studies. Folta (2004) discovered that exposing *Arabidopsis* seedlings to green light increased their early stem length. According to Kim *et al.* (2004a, b) adding green light to the light source enhanced stomatal conductance, leaf development, and dry matter production in lettuce plants (Kim *et al.*, 2004a, b). According to Terashima *et al.* (2009) green light combined with bright white light triggered photosynthesis in sunflower leaves more effectively than red light. A growing number of studies have recently asserted that green light causes adaptive changes in plant morphology and physiology for optimal growth (Folta and Maruhnich, 2007; Terashima *et al.*, 2009; Johkan *et al.*, 2012; Wang *et al.*, 2015). These instances have shown the benefits of green light, but they rarely go into detail on the intensity of green light and how cereal crops respond to it.

In the era of smart agriculture crop variety development and production have got many dimension and more land are struggling for rice cultivation from plain land to high altitudes. The quality of rice seedlings during growth is therefore an important factor in rice production, especially when mechanically transplanting of seedlings to the field. Rice seedlings now a days are grown under vinyl/poly house or greenhouse. But the short day lengths and unfavorable conditions of low natural light in greenhouse are the main limiting factors in nursing vigorous seedlings, which are expected to directly contribute to a plentiful harvest of rice (Pasuquin *et al.*, 2008; Brar *et al.*, 2012). Nursery management in greenhouse is needed before rice young seedlings are transplanted into paddy field.

Additional lights may be used as proper remedy for this problem. However, there is a paucity of data in this research field moreover on the effects of light on rice seedling growth and rice yield. The tiny size, long lifetime, low emitting temperature, narrow band width wavelength emission, and wavelength specificity of light-emitting diodes (LEDs) offer the most promise for plant cultivation in controlled environments (Massa *et al.*, 2008; Jung *et al*,. 2013). Diverse plant species have different morphogenetic and photosynthetic responses to spectral light variations. Such light reactions are important in contemporary plant production methods because the ability to control plant growth, development, and nutritional quality by changing illumination spectra is possible.

The goal of this study was to findm how rice seedling growth changed when they were exposed to green light, and to determine if the influence of light at the seed germinating and seedling stage.

Materials and Methods

Seed material and germination tests

Rice seeds of BRRIdhan52, BRRIdhan81, BRRIdhan86 and BRRIdhan92 (Table 1) were collected from 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
BRRIdhan52	Aman	Submergence tolerant	2010, BRRI
BRRIdhan81	Boro	Premium quality rice	2017, BRRI
BRRIdhan86	Boro	Anther culture derived	2017, BRRI
BRRIdhan92	Boro	Drought tolerant, wheat rice cross	2019, BRRI

Light source and treatments

For the dark treatment of rice seeds, the petri plates were covered with black cotton cloth. Light treatment of the rice seeds with petri plates were kept under illumination using a cool, green light emitting diode source with 6 light and 18 h dark period. Seeds were incubated at 22 ± 2 °C and relative humidity of 82 ± 2 % during the incubation period. Specification of the green 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: -2^0 C ~4^0 C. Distance between green LED light and seeds or seedling were adjusted to get the approximately equal photosynthetic photon flux (PPF). The plants without green light irradiation was 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 petridishes were observed daily 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 >2mm in length. The experiments were continued for 14 days (Ellis and Roberts, 1981).

Germination percent

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, leaf blade, 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. It was 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 (Kouio, 2003).

Measurement of fresh weight and dry weight of the seedling

After 17 days of seed setting 15 seedlings of each petisdish 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.

Germination percentage and growth parameter reduction calculation

It was calculated as, [(parameter value at dark condition – parameter value at light condition)/ parameter value at dark condition] × 100

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).

Results 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: BRRIdhan52, BRRIdhan81, BRRIdhan86, and BRRIdhan92 (Table 2).

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

Variety	Germination (%)	First leaf length (cm)	First leaf blade length (cm)	Root length (cm)	Seedling fresh weight(g)	Seedling dry weight(g)
Dark						
BRRIdhan52	**82** ±1.15	**7.88** ±0.17	**1.99** ±0.014	**5.79** ±0.12	**0.356** ±0.0063	**0.041** ±0.0007
BRRIdhan81	**58** ±1.13	**10.43** ±0.08	**2.69** ±0.016	**5.68** ±0.06	**0.388** ±0.0056	**0.045** ±0.0006
BRRIdhan86	**80** ±1.12	**10.42** ±0.09	**2.25** ±0.007	**5.48** ±0.10	**0.332** ±0.0048	**0.038** ±0.0005
BRRIdhan92	**80** ±1.71	**6.06** ±0.14	**3.19** ±0.108	**6.24** ±0.26	**0.338** ±0.005	**0.039** ±0.0006
Green LEDs						
BRRIdhan52	**66** ±1.73	**5.91** ±0.05	**5.09** ±0.04	**2.90** ±0.058	**0.376** ±0.004	**0.043** ±0.0005
BRRIdhan81	**51** ±2.33	**6.38** ±0.04	**4.44** ±0.10	**2.74** ±0.053	**0.410** ±0.008	**0.047** ±0.0009
BRRIdhan86	**88** ±1.15	**6.04** ±0.01	**5.74** ±0.14	**2.65** ±0.034	**0.451** ±0.003	**0.052** ±0.0004
BRRIdhan92	**70** ±1.70	**7.24** ±0.04	**6.19** ±0.41	**2.96** ±0.022	**0.359** ±0.003	**0.041** ±0.0004

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

Germination

Germination percentages in the dark ranged from 58 to 82 per cent. BRRIdhan52 had the highest percentage of germination, whereas BRRIdhan81 had the lowest. Germination percentages under green light ranged from 51 to 88 per cent. BRRIdhan81 had the highest percentage of germination, whereas BRRIdhan86 had the lowest. Germination percentages were lower than dark under dark condition (Table 2). According to Simpson (1990) that light inducible germination happens in a certain set of environmental conditions in many plant species, those may dependent or independent to light. Early seedling growth and development are fueled by seed reserves, and this heterotrophic lifestyle can endure for several days in the dark (Takano *et al.,* 2005).

First leaf length and leaf blade length

The length of the first leaf in the dark ranged from 6.06 to 10.43 cm. BRRIdhan81 had the longest leaf and BRRIdhan92 had the shortest leaf. The length of the first leaf blade varied from 1.99 to 3.19 cm. BRRIdhan92 had the highest leaf blade length, whereas BRRIdhan52 had the least. The length of the first leaf under green light varied from 5.91 to 7.24 cm. BRRIdhan92 had the longest leaves, whereas BRRIdhan52 had the shortest. The length of the first leaf blade varied from 4.44 to 6.19 cm. BRRIdhan92 had the longest leaf blade, while BRRIdhan81 had the smallest (Table 2). Green light spectra positively increase the first leaf blade length (Plate 1**).** *Kim et al.* (2004a) reported that green light can better penetrate the plant canopy, which potentially increase plant growth by increasing photosynthesis from the leaves in the lower canopy. The effects of green light on enhancing elongation growth were well described in several literatures (Klein *et al.,* 1965; Mandoli and Briggs 1981; Folta 2004 and Zhang *et al.,* 2011)

Root length, seedling fresh and seedling dry weight

In the dark, root length ranged from 5.48 to 6.24 cm, while under green light, root length ranged from 2.65 to 2.96 cm. In both dark and green light growing conditions, BRRIdhan92 had the longest root while BRRIdhan86 had the shortest root (Table 2).

The fresh weight of rice seedlings grown in the dark ranged from 0.332 to 0.388g, while under green light it ranged from 0.359 to 0.451g. In the dark, seedling fresh weight was lowest in BRRIdhan86 and highest in BRRIdhan81. Under green light, BRRIdhan92 had the lowest seedling fresh weight and BRRIdhan86 had the highest. Seedling dry weight in the dark ranged from 0.038 to 0.0.045 g, while under green light it ranged from 0.041 to 0.052 g. In the dark, seedling dry weight was lowest in BRRIdhan81 and highest in BRRIdhan86. Under green light, BRRIdhan92 had the lowest seedling dry weight and BRRIdhan86 had the maximum (Table 2). Irradiance with green light increased seedling fresh and dry weight remarkably in the rice varieties, which agrees with the previous findings of Zhang *et al.*, (2016), who observed change in root morphology and fresh and dry weight accumulation.

(a) Seedlings of BRRIdhan52 in dark

(b) Seedlings of BRRIdhan52 under green light

Plate 1. Effect of dark (a) and green light (b) on germinating seedling of BRRIdhan52.

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

	Germinatio n (%)	**First leaf length (cm)**	**First leaf blade length (cm)**	**Root length (cm)**	**Seedling fresh weight(g)**	**Seedling dry weight(g)**
Germination (%)	**0**	-0.318^{ns}	0.436^{ns}	-0.034^{ns}	-0.365^{ns}	-0.406^{ns}
First leaf length (cm)		**0**	-0.480*	-0.873*	0.980**	0.981**
First leaf blade length (cm)			**0**	0.619^{ns}	-0.643^{ns}	-0.637^{ns}
Root length (cm)				**0**	-0.905*	-0.883^{ns}
Seedling fresh weight(g)					**0**	0.999***
Seedling dry weight(g)						**0**

*, **, ***, **** Indicate significant differences between dark and green LEDs treatment at $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$ and $p \leq 0.0001$ level, respectively. Ns: Not significant at (n-2) df.

Correlation between seed germination and seedling parameters

Correlation coefficient was calculated for germination percent, first leaf length, first leaf blade length, root length, seedling fresh weight and seedling dry weight of four rice varieties (Table 3). Seedling fresh weight and seedling dry weight had the most positive and significant correlation (r = 0.999). Seedling fresh weight (r = 0.980) and seedling dry weight (r = 0.981) were likewise positively correlated with first leaf length. However, there was a negative significant association between first leaf length vs. first leaf blade length (r = -0.480), first leaf length vs. root length (r = -0.873) and root length vs. seedling fresh weight (r = -0.905). The characters studied had no significant correlation with germination percent. Positive significant correlation for the shoot and root traits in rice under green light fully agree with the findings of Zhang *et al.* (2016), who found positive significant correlation in different experiments with rice.

Table 4. Differences in growth parameters of 4 rice varieties with green LEDs light.

Characters	Differences			
	BRRIdhan52	**BRRIdhan81**	**BRRIdhan86**	**BRRIdhan92**
Germination (%)	20	11	**10**	13
First leaf length (cm)	25	39	42	**19**
First leaf blade length (cm)	**156**	**65**	**155**	**94**
Root length (cm)	50	52	52	53
Seedling fresh weight (g)	**6**	**6**	**36**	**6**
Seedling dry weight (g)	**6**	**6**	**36**	**6**

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

Growth advantages of rice supplemented with green light

In the studied rice varieties, germination percent declined by 11 to 20%, with an exception in BRRIdhan86, where germination percent increased up to 10% (Table 4). The length of the first leaf in rice varieties declined by 25 to 42 %, with the exception of BRRIdhan92, which had a 19 percent increase in total length. The first leaf blade length increased 65 to 156 % in the studied varieties, where BRRIdhan52 showed the greatest increase. In all rice cultivars, root length dropped by 50 to 53 percent. In the studied rice varieties, seedling fresh and dry weight increased by 6 to 36%. BRRIDhan86 had the most increase in these two characters. Fall in germination percent, first leaf length and root length reduction indicate that young rice seedling growth was hindered under green light. In this study, it was expected that germination percent, leaf growth and root length may enhanced, but the performance of germinating rice varieties and their young seedlings respond differently to green light. Addition of green light with other light is beneficial for stem and root elongation, but not alone (Zhang *et al.*, 2016). In the present study green light was used alone not with the other spectrum, though the overall contribution of green light to the morphology, metabolism and photosynthesis of young rice seedlings.

Researchers will be able to understand better the effects of green light on rice plant growth and create a greenhouse light environment that produces healthy seedlings using the findings of this study. Before transplanting rice seedlings to field conditions, controlled climates and LEDs may be a practical concern. Designing growth chambers or greenhouse light conditions to maximize economic value for rice growers, to get benefit from an ideal light quality regulation method. From the rice literature it is evident that effect of green light on different have long been neglected than blue, red, far red and other source of light. In the present findings rice seed and seedlings showed response to some extent. Therefore, more research is needed to find out the other combination of lights in comparison with dark in rice improvement, seed production and management.

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