The effect of red, blue, green and white light emitting diodes on pigment content and sugar accumulation in wheatgrass

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Abstract. This research studied the effect of light-emitting diode (LED) on pigment content and sugar accumulation in wheatgrass. The wheatgrass was cultured under different lighting conditions, consisting of white (W), red (R, 660 nm), blue (B, 480 nm), and green (G, 525 nm) LEDs. The daily light integral is 2.33 mol/day in 7 days. The wheatgrass was cultured in a close system at a temperature of 25±1 ℃ and humidity of 75 ± 3 %. In the experiment, the completely randomized design was used with three replications of 100 seedings. The wheatgrass that was grown under red and blue light with ratio 1:1 yield a chlorophyll A of 1.0363 mg/L, chlorophyll B of 0.4189 mg/L, and carotenoid of 0.3208 mg/L. The sugar accumulation of 8.234 mg/L is a maximum under the red, green, and blue treatment with statistical significance.

1. Introduction

Study of the physical responses of plants under light-emitting diodes (LEDs) gains increasing interest [1]. LEDs generally have a narrow emission wavelength that can be combined to produce the desired spectrum. LEDs are more energy-efficient than other light sources. Light is an essential environmental factor whose intensity, quality, and photoperiod affect plant growth. The qualities of light are known to control morphogenesis and growth. For the light spectrum for plant growth, red light and blue light are efficiently absorbed by chlorophyll a and b. The red and blue light have significant impacts on chloroplast biosynthesis [2].

A soluble sugar of the plants is carbohydrate affecting the sweetness. The soluble sugar consists of fructose, glucose, sucrose [3]. Some research reported that red and blue light had an impact on sugar accumulations and compositions, which determine both flavor and quality of vegetables [4]. Green oak grows under a combination of red, blue, and white light, significantly increasing the sugar [5]. The combination of red, blue, and green light can significantly promote sugar accumulation in the potato [6]. Wheatgrass is grown from the wheat seed for a one week and the wheatgrass juice can be squeezed from wheatgrass. Wheatgrass juice can be consumed without any hazardous effect, but it is difficult to drink because of its bitter taste. Wheatgrass juice is rich in nutrients such as vitamins and chlorophyll. The chlorophyll of wheatgrass has health benefits to body humans [7]. Chlorophyll is an essential component for photosynthesis: the chemical process that plants absorb and use energy from light. Chlorophyll structure can change the chemical energy into the sugar such as glucose and fructose.

This study aimed to solve the sugar problems and increase pigment content in the wheatgrass. The experiment used the LED as a light source for photosynthesis instead of sunlight. This method can increase sugar accumulation and pigment content in wheatgrass.
2. Experimental methods

In this experiment, the photosynthetic lighting source for plant growth used the light-emitting diodes (LEDs). The light treatments consist of red LEDs (R, peak = 660 nm), blue LEDs (B, peak = 480 nm), green LEDs (G, peak = 525 nm) and white LEDs (W, 400-700 nm) (TOL-50, Oasistek, Taiwan). The LEDs were combinations of red, blue, green and white LEDs with ratios of R:B = 1:1; R:B:G = 1:1:1, R:B:W = 1:1:1 [4–6]. All the treatments have the same photosynthetic photon flux density (PPFD) of 50 μmol·m⁻²·s⁻¹ and a 16/8-h light/dark photoperiod. The pulse width modulation (PWM) controlled photosynthetic photon flux density. The optical power meter (PM100A, Thorlabs, USA) placed at a distance of 30 cm underneath the LEDs panel for measuring the PPFD in the area of 20 cm². The spectroradiometer (LI-1800, LI-COR, Lincoln, NE, USA) measured a spectral distribution of light treatment.

The experiment is conducted using wheatgrass that grown in the King Mongkut’s Institute of Technology Ladkrabang. The 150 wheat seeds were sown into twelve plastic pots filled with black husk and coconut shell’s hair. The plastic pots are then transferred into chambers illuminated with LED treatments. The solution of wheatgrass used 0.2 g of the fresh leaf. The sample of fresh leaf washed with 80% acetone at 10 ml until the leaf turned white. The solution was supplemented with distilled water to a total volume of 25 ml. The contents of chlorophyll and carotenoid are determined according to the equation of Lichtenthaler [8]. The contents of sugar (fructose, glucose, and sucrose) were determined via the high-performance liquid chromatography (HPLC) based on the standards [9]. The experiment is arranged in a completely randomized design (CRD). The presented data for the growth parameters are the means of three replicates and 100 seedings per replication. The data were analyzed by one-way analysis of variance (ANOVA).

3. Results and discussion

The measurement of average PPFD in the area of 20 cm² and spectral distribution is shown in table 1. The PWM controlled the average PPFD of 50 ± 0.65 μmol·m⁻²·s⁻¹. The spectral distribution of light treatments depends on the PPFD of each LED, as shown in figure 1.

| Light treatment | Average photosynthetic photon flux density (μmol m⁻² s⁻¹) |
|-----------------|----------------------------------------------------------|
|                 | Blue 400-500 | Green 500-600 | Red 600-700 | White 400-700 | Total         |
| RB = 1:1       | 25.38        | 0             | 25.34       | 0             | 50.72         |
| RBG = 1:1:1    | 16.84        | 17.01         | 16.82       | 0             | 50.67         |
| RBW = 1:1:1    | 16.53        | 0             | 16.87       | 16.99         | 50.39         |
| W              | 0            | 0             | 0           | 50.79         | 50.79         |

The results of the chlorophyll and carotenoid contents in the wheatgrass are shown in figure 2(A). Chlorophyll a, chlorophyll b, and carotenoid content significantly increased in the wheatgrass grown under RB (p < 0.05) is 1.0363 mg/g, 0.4189 mg/g, and 0.3208 mg/g. Using RB in the ratio 1:1 of this research is consistent with previous studies that can increase the pigment content [4]. In contrast, wheatgrass grown under the W treatment yielded the lowest chlorophyll a, chlorophyll b, and carotenoid content at 0.6926 mg/g, 0.2613 mg/g, and 0.2016 mg/g. The pigment of plants harvests the photon energy and convert to a chemical product. The pigment content variations in different light treatments show the photosynthesis rate of the wheatgrass. The white light, which has a wide range spectrum, has a low efficiency because it has a wide range spectrum.
Figure 1. Spectral distribution of four lighting treatments, including (A) R:B = 1:1, (B) R:B:G = 1:1:1, (C) R:B:W = 1:1:1 and (D) white LED.

The soluble sugar in plants is composed of sucrose, glucose, and fructose [3]. Eissa et al [10] studied sugar in the wheatgrass juice. Their results found glucose and fructose. For in this finding only found fructose and no other sugar due to using different planting mediums or wheat breed. The contents of fructose in wheatgrass treated with RGB treatment was significantly higher than that in wheatgrass treated with the other treatments are shown in figure 2. The combination of RGB light significantly enhanced fructose (p<0.05) content by 8.234 mg/L and higher than the other treatment. The sugar accumulation of this experiment corresponds to Kim et al and Ma et al [5,11], which found that the combination of RBG LEDs increased the amounts of soluble sugar.
Figure 2. The pigment contents and sugar accumulation of wheatgrass were planted in different light treatments: (A) pigment content, (B) sugar accumulation. The bars indicate standard errors.

4. Conclusion
In a controlled environment, it is critical to optimize the spectral quality of light sources for plant production in indoor farms. This study shows that the quality of light is an essential factor which enhances the accumulation of biomass. The wheatgrass grown under RBG had an impact on sugar accumulation. The results only found fructose of 8.234 mg/L is a maximum with statistical significance. The green light was unimportant in driving photosynthesis because of its low absorptive coefficient in chlorophylls. However, the green light is repeatedly reflected from chloroplast to chloroplast. Finally, the pigment can absorb green light into the photosynthesis part [11]. The addition of green light increased biomass. The wheatgrass that is grown under RB treatment effectively yields a chlorophyll A of 1.0363 mg/L, chlorophyll B of 0.4189 mg/L, and carotenoid of 0.3208 mg/L. In the future, this study can apply to increase vitamins or nutrients in the wheatgrass.

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