ผลของความเข้มแสงจากชุดหลอดแอลอีดีสำหรับการเพาะปลูกที่มีต่อผักสลัดเรดโอ๊คในระบบโรงเรือนไฮโดรโปนิกส์

The Effect of Light Intensity from Growth Light-emitting Diode on Red Oak in Hydroponics Greenhouse System

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บทคัดย่อ

ในบรรดาปัจจัยทางสภาพแวดล้อมที่เกี่ยวข้องกับการเจริญเติบโตของพืช ปัจจัยทางด้านแสงสว่างถือว่าเป็นส่วนที่สำคัญอย่างหนึ่งซึ่งส่งผลต่อการเพาะปลูกพืชโดยผ่านกระบวนการสังเคราะห์แสง โดยทั่วไปพืชจะดูดซับแสงอาทิตย์เป็นหลัก และมีแนวโน้มในการดูดซับช่วงแสงสีน้ำเงินและสีแดง ซึ่งช่วงแสงดังกล่าวนี้มีผลต่อการเจริญเติบโตของพืชเป็นอย่างมาก สำหรับพื้นที่เพาะปลูกที่มีอย่างจำกัด พืชจะเจริญเติบโตภายในห้องหรือโรงเรือนที่ซึ่งแสงอาทิตย์อาจมีไม่เพียงพอต่อความต้องการของพืช ดังนั้น การเพิ่มแหล่งกำเนิดแสงนอกเหนือจากแสงอาทิตย์ จึงสามารถช่วยเพิ่มความเข้มแสงหรือความสว่างภายในโรงเรือนหรือพื้นที่เพาะปลูกได้ ในงานวิจัยนี้จึงได้ทำการออกแบบและสร้างชุดหลอดแอลอีดีเพื่อใช้ในการศึกษาผลของความเข้มแสงจากชุดหลอดแอลอีดีที่ช่วงความยาวคลื่นแสงสีแดง สีขาว และสีน้ำเงิน ที่มีต่อการเจริญเติบโตของพืช ซึ่งพิจารณาจากตัวแปรคือ ความสูงต้น ความยาวราก น้ำหนัก และน้ำหนักแห้งของพืช โดยได้ทำการออกแบบลักษณะการจัดเรียงหลอดแอลอีดี จำนวน 50 หลอด ลงบนวัสดุติดตั้งที่มีความกว้าง 30 ซม. และความยาว 30 ซม. ชนิดของแสงทั้งหมดที่ใช้ในการศึกษาคือชุดหลอดแอลอีดีสีแดง สีขาว และสีน้ำเงินที่มีความส่องสว่างเท่ากับ 327, 1,078 และ 4,338 ลักซ์ ตามลำดับ โดยนำผลการทดสอบที่ได้มาเปรียบเทียบกับผลจากชุดควบคุมคือชุดหลอดฟลูออเรสเซนต์ที่มีความส่องสว่างเท่ากับ 2,028 ลักซ์ พืชตัวอย่างที่ใช้ในการทดสอบคือผักสลัดชนิดเรดโอ๊ค ซึ่งปลูกด้วยระบบไฮโดรโปนิกส์แบบรากจุ่ม

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(Deep Flow Technique) ภายในโรงเรือนและกำหนดให้ได้รับแสงจากชุดหลอดไฟที่ติดตั้งที่ระดับความสูง 30 ซม. จากถาดปลูกพืช เมื่อสิ้นสุดช่วงการทดสอบ (21 วัน นับจากการพืชตัวอย่างเข้าสู่โรงเรือนทดสอบ) พบว่า ค่าเฉลี่ยของความสูงต้นและความยาวรากสูงสุดพบในผักสลัดเรดโอ๊คที่ได้รับแสงจากชุดหลอดแอลอีดีส น้ำเงิน ความสูงต้นและความยาวรากสูงสุดมีค่าเท่ากับ 28.7 และ 23.1 ซม. น้ำหนักสดในส่วนต้นและรากมีค่าเท่ากับ 11.82 และ 1.12 กรัม/ต้น น้ำหนักแห้งในส่วนต้นและรากมีค่าเท่ากับ 0.42 และ 0.06 กรัม/ต้น ตามลำดับ เมื่อเปรียบเทียบกับค่าการเจริญเติบโตของผักสลัดเรดโอ๊คในกลุ่มที่ได้รับแสงจากหลอดฟลูออเรสเซนต์พบว่า ความสูงต้นของผักสลัดเรดโอ๊คที่ปลูกด้วยชุดหลอดแอลอีดีสีน้ำเงินมีค่าน้อยกว่า 3.7% และความยาวรากของผักสลัดเรดโอ๊คที่ปลูกด้วยชุดหลอดแอลอีดีสีน้ำเงินมีค่ามากกว่า 9.5% อย่างไรก็ตามพบว่า น้ำหนักสดและน้ำหนักแห้งของผักสลัดเรดโอ๊คที่ปลูกด้วยชุดหลอดแอลอีดีสีน้ำเงินและชุดหลอดฟลูออเรสเซนต์มีค่าไม่แตกต่างกัน เมื่อวัดค่าการใช้พลังงานของชุดหลอดแอลอีดีสีแดง สีขาว และสีน้ำเงิน มีค่าเท่ากับ 2.27, 2.06 และ 2.04 วัตต์ ตามลำดับ จากผลการศึกษาพบว่า การเพิ่มค่าความเข้มแสงหรือความส่องสว่าง (จาก 327 เป็น 4,338 ลักซ์) ส่งผลทำให้การเจริญเติบโตของผักสลัดเรดโอ๊คเพิ่มขึ้นตามไปด้วย แต่ในทางตรงกันข้าม ในกรณีของผักสลัดเรดโอ๊คที่ปลูกด้วยชุดหลอดแอลอีดีสีขาวที่ความสว่าง 1,078 ลักซ์ มีการเจริญเติบโตที่น้อยกว่าผักสลัดเรดโอ๊คที่ปลูกด้วยชุดหลอดแอลอีดีสีแดงและสีน้ำเงิน

คำสำคัญ : หลอดแอลอีดี; ความเข้มแสง; การเจริญเติบโตของพืช; การปลูกพืชไฮโดรโปนิกส์; การประหยัดพลังงาน

Abstract

Among various environmental factors for plant growth, light is one of the most important variable affecting plant cultivation through the process of photosynthesis. Plantsusuallyabsorbsunlightandespeciallytendtouseredandbluelightofthevisualspectrum which have the greatest impact on plant growth. For limited cultivated area, plants were grown under chamber or greenhouse where sunlight may be limited. Thus, supplementing limited sunlight with artificial lighting can help increasing the light intensity in greenhouse. In this study, the array of light-emitting diodes (LEDs) was designed to determine the effect of light intensity with different spectrum such as red, white and blue light on plant growth; shoot length, root length, fresh weight and dry weight. The arrangement of 50 LEDs on the plate (30 cm x 30 cm) was designed. The light treatments were 327 Lux of red light, 1,078 Lux of white light, 4,338 Lux of blue light and 2,028 Lux of fluorescent light as control. Red Oak were hydroponically grown with deep flow technique (DFT) in growth room and were irradiated with light source at 30 cm from the top of plant canopy. At the end of the light treatment (21 days after transplanting into growth room), the maximum shoot length and root length were obtained in Red Oak with blue light compared with LED lighting. Shoot length

and root length of Red Oak treated with blue light were 28.7 and 23.1 cm, fresh weight of shoot and root were 11.82 and 1.12 g/plant, and dry weight of shoot and root are 0.42 and 0.06 g/plant, respectively. Shoot length of Red Oak with blue light was 3.7% lower and root length was 9.5% greater than plant under fluorescent treatment. However, no significant differences were observed in fresh weight and dry weight of Red Oak between in blue light and fluorescent light. The measured power consumption of red, white and blue LED were 2.27, 2.06 and 2.04 W, respectively. In conclusion, our results indicated that the growth of Red Oak was strongly influenced by blue and red light, when the light intensity drastically increased (from 327 to 4,338 Lux), the growth parameters increased. In the other hand, the growth under white light with 1,028 Lux was decreased and less than plant growth under red light and blue light.

Keywords : Light-emitting Diode; Light Intensity; Plant Growth; Hydroponics Plant Production; Energy Saving

Introduction

The light-emitting diodes are a semiconductor light source. The color of light or wavelength is determined by the energy band gap of the semiconductor. Modern LEDs are available the visible wavelengths with very high brightness. LEDs become to be used in multitasking lighting due to many advantages over the early light sources including small package, long useful life, minimum heating, wavelength specificity and narrow bandwidth, low energy consumption and high efficiency in lumens per Watt.

In agriculture, related with this study, LEDs are now used in application as the secondary or supplement lighting for plant in greenhouse or limited cultivated area that the amount of sunlight may be limited, because of specific wavelength and a narrow bandwidth (Johkan et al., 2012). As we known that light is one of the most important factors in plant growth and each emitted color spectrum triggers different morphogenetic and photosynthetic responses that can vary among different plant species (Lin et al., 2013). Plants are generally tend to used more of blue and red light. In the LEDs generated light, the conventional light colors are made from a variety of semiconductor materials. Blue LEDs are based on the semiconductors Gallium Nitride (GaN) and Indium Gallium Nitride (InGaN). Red LEDs are made with Gallium Arsenide (GaAs). In RGB system, white light from LEDs can be formed by the most method of mixing differently colored light; red (R), green (G) and blue (B). In the previous study,

blue light is involved in many plant activities such as photomorphogenesis and photosynthesis (Whitelam G. and Halliday, K., 2007), but the response highly from plants depends on the intensity of blue light. Most studies with blue light only and blue mixed with red and white light indicated that containing irradiation produced higher plant biomass accumulation (Matsuda et al., 2008; Yorio, N.C. et al., 2001). Red light induces the leaf blades elongation of lettuce and lettuce treated with blue-containing LEDs light appeared reddish leaves, whereas the leaves of lettuce treated with red light were bright green (Johkan et al., 2012). The fresh weight and dry weight of lettuce with blue light increased compared with fluorescent and red light (Johkan et al., 2012). However, the application of red-blue-white (RBW) has been studied, supplemental light quality can be used to create the growth of plants grown under RBW LEDs light that brings the maximizing in economic efficiency of plant production (Lin et al., 2013).

In this study, the effects of light intensity with different light spectrum such as blue, red and white LEDs light on the growths of Red Oak in hydroponics greenhouse were reported. Shoot length, root length, fresh weight, dry weight and leaf number of Red Oak under different light treatments were also determined.

Methodology

Plant and growth conditions

Seeds of Red Oak (Lactuca sativa L.) were sown in substrate and hydroponically grown for 21 days in controlled-environment. At 21 days after sowing (DAS) , all of the 60 Red Oak seedlings were transplanted into hydroponics greenhouse system with mixing of nutrient solution A and B (6 ml per 1 litre of water). The nutrient solution was renewed every week for summer or 2 weeks for winter and adjusted to pH 5.5 – 6.5 for lettuce. The photoperiod was maintained at 16 h and 8 h for dark periods. The air temperature and relative humidity for all treatment were maintained throughout the experiment at lower than 30°C and 70%, respectively. The plants were irradiated with 3 different light treatment of LEDs, namely blue light, red light and white light. Plants were harvested at 42 days after sowing. The experiment was independently performed triple for a randomized design of light treatment conditions and plant measurements represented means of 15 plants (five plants for each replicates).

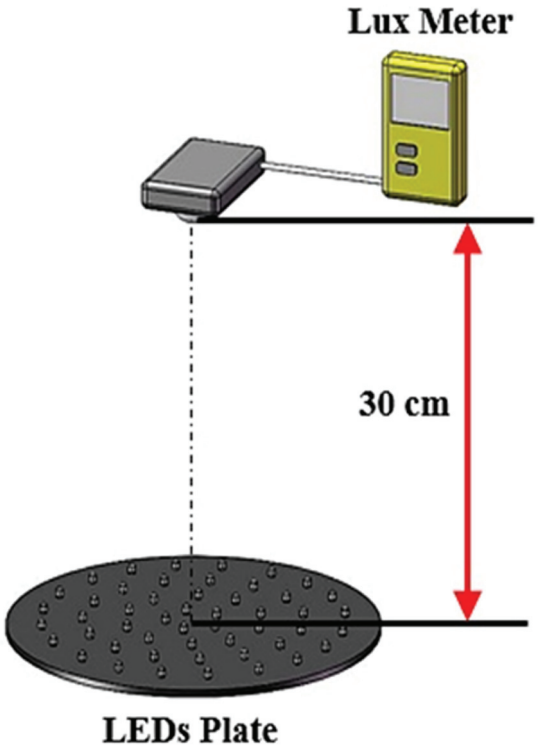

Figure 1 A illuminance measurement of LEDs plate with lux meter at test plane 30 cm

Light treatments

Blue (B), red (R) and white (W) LEDs were used in the design through-hold type with diameter of 5 mm, a viewing angle of 30° and forward voltage 3 V for blue and white light and 2 V for red light at current 20 mA. Fifty through-hold of LEDs were arranged on a square plate with dimension of 30 cm with radial arrays because of high irradiance efficiency. The radial arrays were constant brightness area at the center with the fewest number of LEDs (Chen and Wu., 2010). The peak emission of the blue light and red light were 454 nm and 660 nm, respectively (Lin et al., 2013). The white light from trichromatic LEDs had the peak emission from 460, 540 and 615 nm (Lei et al., 2007). The illuminance of LEDs light were measured with Lux meter and recorded 30 cm below the panel of LEDs plate as shown in Figure 1. Red Oak were hydroponically grown with deep flow technique (DFT) in growth room (Figure 2) and were irradiated with light source at 30 cm from the top of the plant canopy. The light treatments for Red Oak in this experiment consisted of 327 Lux of red light, 1,078 Lux of white light, 4,338 Lux of blue light and 2,028 Lux of fluorescent (FL) light as control.

Figure 2 Deep flow technique (DFT) system in controlled growth room

Plant growth measurements

Shoot length, root length, fresh weight (FW), dry weight (DW) and leaf number which the parameters were measured. Shoot length and root length of Red Oak were measured and recorded every week. Red Oak was harvested at 42 days and recorded shoot length, root length and leaf number. Then the plant samples were determined for fresh weight and dry weight separating shoot and root section. Plant samples were dried oven for 72h at 72^{o}C before dry weight measurement.

Results and discussion

Red Oak, one of the famous lettuce is widely commercially grown in hydroponics greenhouse due to its fast growth and high market value. The adding of LEDs as the supplement light for Red Oak in hydroponics greenhouse may help the plant grow faster and increase the plant production.

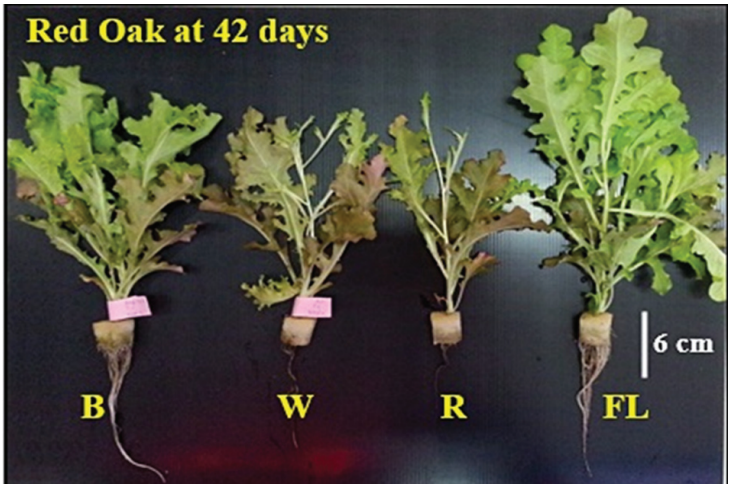

Figure 3 Morphology of Red Oak treated with 4 difference light sources; blue LEDs, white LEDs, red LEDs and fluorescent light at 42 days after sowing

Figure 3 presents the morphology of Red Oak with the difference light sources at 42 days after sowing. The most normal appearance and natural morphology of Red Oak were obtained in Red Oak with fluorescent and blue light. Red Oak treated with red light and white light shown a long stem with small leaf and short root length. According to Johkan (Johkan et al., 2012), healthy roots can support the shoot growth by fully absorbing nutrient solution. In contrast, sprouting seedling in which stems rapidly elongate due to low light intensity have short and small roots which decreases plant growth. In addition, the appeared leaf area of Red Oak under blue light were larger than Red Oak under red light and white light. However, new leaves that grow after transplanting shown less reddish leaves than before and become bright green.

Red Oak under blue light shown the highest increasing in rate of shoot and root elongation after 1 week in experiment. At the end of the treatment (21 days after transplanting into growth room), the maximum shoot length and root length were obtained in Red Oak with blue light compared with LEDs lighting. Shoot length and root length of Red Oak treated with blue light were 28.7 and 23.1 cm, respectively (Figure 4 and Figure 5). Shoot length of Red Oak with blue light was 3.7% lower and root length was 9.5% greater than Red Oak under fluorescent control. Red Oak under blue light had a significantly higher root length (23.1 cm) comparing with Red Oak under red light (15.0 cm) and white light (12.9 cm) treatment. No significant differences were observed in root length of Red Oak with red light and white light after 21 days in experiment. At the end of experiment, root length were increased 83, 24 and 9% for Red Oak treated with blue, red and white light compared with Red Oak at 21 days.

Result of the fresh weight and dry weight including shoot and root section of Red Oak influenced by the light intensity are shown in Table 1. Shoot FW and DW, and root FW and DW of Red Oak were the greatest when irradiated with blue light, for all LEDs light source. However, no significant differences were observed in FW and DW of Red Oak with blue light and fluorescent. The greatest FW and DW were observed in Red Oak with blue light for all compared with LEDs light sources, fresh weight of shoot and root were 11.82 and 1.12 g/plant, and dry weight of shoot and root are 0.42 and 0.06 g/plant, respectively. There were no significant differences in leaves number of Red Oak among the light treatment.

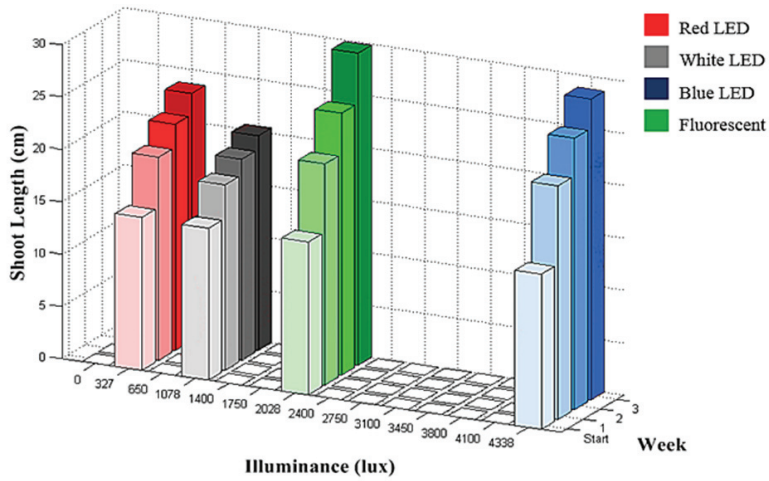

Figure 4 Effect of illuminance on shoot length of Red Oak

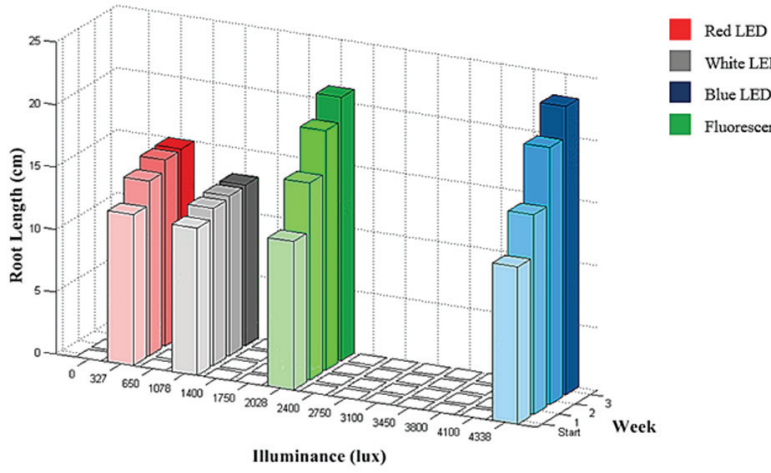

Figure 5 Effect of illuminance on root length of Red Oak

Table 1 Effects of illuminance on fresh weight, dry weight and leaves number of Red Oak at 42 days

Light Source	Illuminance (Lux)	Fresh Weight (g/plant)		Dry Weight(g/plant)		Leaves Number
		Shoot	Root	Shoot	Root	
R LED	327	5.76±1.42	0.40±0.17	0.2182 ±0.0570	0.0263 ±0.0107	13.00±1.47
W LED	1,078	4.30±1.94	0.34±0.16	0.1728 ±0.0799	0.0202 ±0.0104	9.92±1.56
B LED	4,338	11.82±4.81	1.12±0.64	0.4202 ±0.1474	0.0558 ±0.0273	11.78±2.11
FL	2,028	15.32±4.38	1.25±0.64	0.6267 ±0.1859	0.0612 ±0.0197	13.63±2.33

Conclusions

In this study, growth measurement including shoot length, root length, fresh weight, dry weight and leaves number were greatly affected by blue LEDs light. Irradiation with blue light increased the growth of Red Oak, but shoot length, fresh weight and dry weight were less than that Red Oak treated with fluorescent at 42 days. Blue LEDs light tends to stimulate and increase biomass production or dry weight. In conclusion, our results indicated that growing Red Oak in hydroponics greenhouse under blue LEDs light is useful in stimulating the growing after transplant into limited sunlight cultivated area. The power consumption of red, white and blue LEDs were 2.27, 2.06 and 2.04 W, respectively. Moreover, according to Yorio (Yorio, N.C. et al., 2001), it was higher in dry weight of lettuce under red light supplemented with blue light than lettuce under red light only. Thus, further investigation about the mixing ratio of blue and red LEDs are needed to improve for increasing the plant growth in the future.

Acknowledgement

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