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EFFECTS OF COLOR LED LIGHT INTENSITIES AND DIFFERENT PHOTOPERIOD REGIMES ON GROWTH OF HYDROPONIC LETTUCE (*Latuca sativa* L.)

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ABSTRACT

This study was carried out to determine the effects of color LED light intensities and different photoperiod regimes on the growth of hydroponic lettuce. Four different light intensity treatments were used including 1 LED light NCM 3000K – purple LED: 75% red, 25% blue (48 µmol/m^2.s PPFD - Photosynthetic photon flux density); 2 LED lights NCM 3000K – purple LED: 75% red, 25% blue (80 µmol/m^2.s PPFD); 3 LED lights D NCM01 L/30W – White LED (60 µmol/m^2.s PPFD) and 3 LED lights NCM 3000K – purple LED: 75% red, 25% blue (98 µmol/m^2.s PPFD), with a combination of five photoperiod regimes of 6/18, 9/15, 12/12, 18/6 and 24/0 (light/dark). Results showed that the 80-24/0 (2 purple LEDs – 24 hours light/0 hour dark) treatment yielded the highest production on fresh weight (34.93 g/plant) and the production of 60-24/0 (3 white LEDs -24 hours light/0 hour dark) and 80-18/6 (2 purple LEDs – 18 hours light/6 hour dark) treatments were 28.95 and 27.22 g/plant, respectively. The highest length of main stem values at interaction treatments among 3 white LED treatment were 26.18 and 20.04 cm for the 24/0 and 18/6 treatments, respectively and the leaf number (17.60 and 16.38 leaves), leaf length (10.31 and 10.97 cm) and leaf width (9.91 and 7.36 cm) at interaction treatments between 2 purple LEDs with 18/6 and 24/0 treatments were higher than others. The interaction among 18/6 and 24/0 treatments with 2 and 3 purple LED treatments showed the highest chlorophyll value (3.92-4.75 µg/g) and the lowest value at 6/18 treatment with four different light intensities (1.25-1.40 µg/g). Thus, 80-24/0 and 80-18/6 treatments showed the best result for the growth of hydroponic lettuce variety GN 63.

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1 INTRODUCTION

Agriculture is influenced by many factors. Global climate change has been considered as a crucial impact to agriculture such as flood, drought, global warming and rising sea water level. It makes the unstable agricultural production. In addition, the rapid increase of population and urbanization makes reduction in agricultural land area. Accord-

ing to Buringh and Dudal (1987), one of the reasons for the reduction of agricultural land area was the increase of population (about 80 million peoples per year). Finding a way to mitigate these effects to agriculture productions and food safety is important and it has been conducted by plenty of institutions and private sectors. Plant factories are very popular around the World and are expected to provide a stable source of chemically and biologically safe food (Shimokawa *et al.,* 2014). Plant factory is an enterprise which produces crops or vegetables under control of all the environmental elements for plant growth such as light, temperature, humidity, carbon dioxide, density and scheduled production (Yano Research, 2011

Recently, the light emitting diode (LED) has spread as a new light source for a plant factory (Shimizu *et al.,* 2011). LED lamps have many benefits such as more different wavelengths, small size, long operating lifetime and low electricity consumption (Gupta and Jatothu, 2013). In addition, the red and blue wavelengths of LED lamps are expected to be used effectively for plant growth because it is consistent with the maximum absorption of chlorophyll (Shimokawa *et al.,* 2014).

In Vietnam, lettuce is one of the necessary vegetables for daily meal. Traditional agriculture for growing lettuce is often in field and leads low production and unsafe because of using more pesticides to protect crops. Thus vegetable and food safety problems have become very important issues. There are not too many researches on using LED lamps in hydroponic vegetables in Viet Nam. The study using LED lamps to grow hydroponic lettuce will be more promising. Thus this study is carried out to determine the effects of color LED light intensities and different photoperiod regimes on the growth of hydroponic lettuce.

2 MATERIALS AND METHODS

The experiment was carried out at greenhouse of Crop Science Department, College of Agriculture and Applied Biology, Can Tho University, from May 20th to June 25th, 2015. Lettuce variety GN 63 supplied by Gino company, Vietnam was used in this study. This variety grows in 45 to 50 days, average yield 1 ton/1.000 m^2 (Seed packing information) .Seeds were germinated in a tray with coconut dirt under shade condition (reduced 25% directed sunlight). After seven days, seedlings were transferred to iron shelves equipped LED lamps (Fig. 1). The shelves were covered by black plastic to prevent the light from different treatments at photoperiod regime factor.

The temperature and humidity in greenhouse ranged from 32 to 35^{o}C and 58% to 70%, respectively.

There were four LED lamps types including:

– 1 LED light NCM 3000K – purple LED: 75% red lamps, 25% blue lamps (48 µmol/m^2.s PPFD - Photosynthetic photon flux density)

– 2 LED lights NCM 3000K – purple LED: 75% red lamps, 25% blue lamps (80 µmol/m^2.s PPFD)

– 3 LED lights D NCM01 L/30W – White LED lamps (60 µmol/m^2.s PPFD)

– 3 LED lights NCM 3000K – purple LED: 75% red lamps, 25% blue lamps (98 µmol/m^2.s PPFD)

All LED lamps were supplied by Rang Dong Light Source & Vacuum Flask Join Stock Company, RALACO.

Fig. 1: Showing arrangement of experiment shelves and LED lamps

Experiment was laid out as factorial with two factors. The first factor was color LED intensities including four treatments corresponding to four color LED lamps. The second factor was different photoperiod regimes including five treatments corresponding to five photoperiod regimes as 6/18, 9/15, 12/12, 18/6 and 24/0 (light/dark). Total treatments were 20 with four replications and four containers (each container was transplanted 1 seedling) in each replication.

Preparing lettuce seedlings for hydroponic and nutrient solution: Uniform-sized seedlings of lettuce at seven days after germinating were individually raised in a small plastic container with high is 10 cm and diameter is 7 cm, then mounted into Styrofoam plate with eight holes, and placed in a tray (the length of tray is 60 cm and width is 40 cm) filled with 4 liters nutrient solution. The Hoagland nutrient solution using in this experiment was supplied by Laboratory of Crop Science Department, College of Agriculture and Applied Biology, Cantho University. Four liters nutrient solution was used for every tray and added once a week (1 liter nutrient solution/time).

Data collection:

After 35 days of cultivation, the data were collected and measured for length of main stem, leaf number, leaf length, leaf width, fresh weight and chlorophyll amount. The leaf length and leaf width were measured in the site of the largest leaf. The N, N-dimethyl formamide method was used to analyze chlorophyll value (Moran, 1982). Data were analyzed statistically by using the SPSS 16.0 software. F test and Duncan's Multiple Range Test were used to compare the mean values among the tests at 95% probability.

3 RESULTS AND DISCUSSIONS

After 35 days, the average stem length of 3 white LED treatments was the highest value of 13.54 cm and differed significantly with other treatments (Table 1). The average stem length of 3 purple LED treatments obtained the lowest value (9.73 cm). For photoperiod factor, the lowest stem length was found at 24/0 and 18/6 (light/dark) treatments (15.70 and 14.60 cm respectively) and the lowest value was at 6/18 treatment (6.06 cm).

Table 1: The stem length (cm) of hydroponic lettuce grown under four LED light intensities combined with 5 different photoperiod regimes at 35 days

Photoperiod regimes (A)	LED light intensity (B)				Average
	1 purple	2 purple	3 white	3 purple	
6/18 (L/D)	5.74^{c}	4.88^{c}	5.17^{d}	8.46	6.06^{d}
9/15 (L/D)	8.06^{c}	10.28^{b}	11.13^{c}	9.93	9.85^{c}
12/12 (L/D)	12.09^{b}	12.41^{ab}	13.76^{c}	10.28	12.14^{b}
18/6 (L/D)	15.12^{ab}	12.97^{a}	20.04^{b}	19.26	14.60^{a}
24/0 (L/D)	17.28^{a}	11.49^{ab}	26.18^{a}	7.87	15.70^{a}
Average	10.6^{C}	11.66^{B}	13.54^{A}	9.73^{D}	
F (A)			**		
F (B)			**		
F (A*B)			**		
CV. (%)			11.05		

*The values in each column followed by different normal characters and in each row followed by different capitalize characters are significantly different (Duncan test, P < 0.05). L/D: (light/dark). **: Significant at P ≤ 0.01*

The interaction among 3 white LED treatments showed that the high main stem length values were 26.18 and 20.04 at 24/0 and 18/6 treatments, respectively. These results were inconsistent with research of Kang *et al.* (2013). This different can be explained by effect of light intensities and photoperiod on different plants. The length of main stem would be a disadvantage of lettuce because it is very easy to flop.

Values of leaf number, leaf length and leaf width obtained in the treatment of 2 purple LEDs (80 µmol/m^2.s PPFD) were greater than other light intensity treatments. For photoperiod treatments, the better results of leaf number, leaf length and leaf width were found in 18/6 and 24/0 treatments (Table 2, Table 3, Table 4 and Fig. 2).

Table 2: The leaf number of hydroponic lettuce grown under four LED light intensities combined with 5 different photoperiod regimes at 35 days

Photoperiod regimes (A)	LED light intensities (B)				Average
	1 purple	2 purple	3 white	3 purple	
6/18 (L/D)	4.00^{c}	4.25^{c}	3.54^{d}	4.50^{d}	4.07^{e}
9/15 (L/D)	6.19^{bc}	8.25^{b}	6.13^{c}	8.48^{c}	7.26^{d}
12/12 (L/D)	7.06^{b}	10.50^{b}	8.88^{b}	10.19^{b}	9.16^{c}
18/6 (L/D)	13.31^{a}	17.60^{a}	14.06^{a}	14.81^{a}	14.95^{a}
24/0 (L/D)	11.27^{a}	16.38^{b}	16.25^{a}	11.19^{b}	13.77^{b}
Average	8.37^{C}	11.40^{A}	9.78^{B}	9.83^{B}	
F (A):			**		
F (B):			**		
F (A*B):			**		
CV (%):			14.84		

The values in each column followed by different normal characters and in each row followed by different capitalize characters are significantly different (Duncan test, P < 0.05)

*L/D: (light/dark).**: Significant at P ≤ 0.01*

The interaction among 2 purple LED treatment at 18/6 and 24/0 treatments showed leaf number (17.60 and 16.38 leaves), leaf length (10.31 and 10.97 cm) and leaf width (9.91 and 7.36 cm) were higher than most of other treatments**.** The present results are inconsistent as compared with previous studies (Kang *et al.*, 2013, Shimokawa *et al.,* 2014). It probably due to difference in light intensity and photoperiod, as each plant had its optimal light intensity and appropriate photoperiod for growth and development. LED had variable effects on different plant species (Li *et al.,* 2012). These results showed that LED light intensity and photoperiod effected on the leaf number, leaf length and leaf width (Morrow, 2008). The leaf number, leaf length and leaf width play an important role on photosynthesis and production.

Table 3: The leaf length (cm) of hydroponic leaf lettuce grown under four LED light intensities combined with 5 different photoperiod regimes at 35 days

Photoperiod regimes (A)	LED light intensities (B)				Average
	1 purple	2 purple	3 white	3 purple	
6/18 (L/D)	2.73^{c}	2.63^{d}	2.31^{d}	3.99^{b}	2.92^{d}
9/15 (L/D)	6.03^{b}	7.51^{c}	6.02^{c}	7.03^{a}	5.32^{c}
12/12 (L/D)	7.98^{b}	9.40^{b}	10.54^{a}	8.11^{a}	9.01^{b}
18/6 (L/D)	12.40^{a}	10.31^{ab}	8.33^{b}	6.74^{a}	9.45^{b}
24/0 (L/D)	13.71^{a}	10.97^{a}	10.98^{a}	7.64^{a}	10.83^{a}
Average	8.57^{A}	8.16^{AB}	7.64^{B}	6.70^{C}	
F (A):			**		
F (B):			**		
F (A*B):			**		
CV. (%):			10.02		

The values in each column followed by different normal characters and in each row followed by different capitalize characters are significantly different (Duncan test, P < 0.05)

*L/D: (light/dark).**: Significant at P ≤ 0.01*

(a) **(b)**

(c) **(d)**

Fig. 2: Lettuce at 35 days. (a): 1 purple LED treatment (*48 µmol/m².s PPFD)*; (b): 2 purple LEDs treatment *(80 µmol/m².s PPFD),* (c): 3 white LED treatment (*60 µmol/m².s PPFD)* and 3 purple LED treatment *(98 µmol/m².s PPFD)* combined with five photoperiod regimes (6/18, 9/15, 12/12,18/6 and 24/0) from left to right

Table 4: The leaf width (cm) of hydroponic leaf lettuce grown under four LED light intensities combined with 5 different photoperiod regimes at 35 days

Photoperiod regimes (A)	LED light intensities (B)				Average
	1 purple	2 purple	3 white	3 purple	
6/18 (L/D)	0.78^{c}	0.71^{e}	0.65^{e}	1.08^{d}	0.80^{d}
9/15 (L/D)	2.16^{b}	2.96^{d}	1.68^{d}	3.31^{c}	2.52^{c}
12/12 (L/D)	2.26^{b}	5.18^{c}	4.63^{c}	5.15^{b}	4.31^{b}
18/6 (L/D)	8.01^{a}	9.91^{a}	7.28^{b}	8.67^{a}	8.47^{a}
24/0 (L/D)	8.71^{a}	7.65^{b}	9.09^{a}	8.09^{a}	8.39^{a}
Average	4.38^{B}	5.28^{A}	4.67^{B}	5.26^{A}	
F (A):			**		
F (B):			**		
F (A*B):			**		
CV. (%):			9.93		

The values in each column followed by different normal characters and in each row followed by different capitalize characters are significantly different (Duncan test, P < 0.05)

*L/D: (light/dark).**: Significant at P ≤ 0.01*

Fresh weight of lettuce was significantly affected by light intensity (Table 5), the highest value obtained at 2 purple LEDs (80 µmol/m^2.s) treatment (13.64 g). The lowest fresh weight was observed in the treatment of 1 purple LED (48 µmol/m^2.s). As the same result, photoperiod also effected on the fresh weight of lettuce, 24/0 (light/dark) treatment showed the highest value with the fresh weight of lettuce was 24.70 g/plant, and the lowest value at 6/18 treatment (0.14g/plant).

Table 5: Fresh weight (g/plant) of hydroponic leaf lettuce grown under four LED light intensities combined with 5 different photoperiod regimes at 35 days

Photoperiod regimes (A)	LED light intensities (B)				Average
	1 purple	2 purple	3 white	3 purple	
6/18 (L/D)	0.13^{b}	0.09^{d}	0.14^{d}	0.19^{e}	0.14^{e}
9/15 (L/D)	1.02^{b}	1.75^{d}	0.59^{d}	1.84^{d}	1.30^{d}
12/12 (L/D)	0.82^{b}	4.22^{c}	3.02^{c}	4.91^{c}	3.25^{c}
18/6 (L/D)	13.89^{a}	27.22^{b}	15.37^{b}	19.06^{b}	18.89^{b}
24/0 (L/D)	13.68^{a}	34.93^{a}	28.95^{a}	21.28^{a}	24.70^{a}
Average	5.91^{C}	13.64^{A}	9.61^{B}	9.46^{B}	
F (A):			**		
F (B):			**		
F (A*B):			**		
CV. (%):			10.04		

The values in each column followed by different normal characters and in each row followed by different capitalize characters are significantly different (Duncan test, P < 0.05)
*L/D: (light/dark).**: Significant at P ≤ 0.01*

The 80-24/0 (2 purple LEDs – 24 hours light/0 hour dark) treatments resulted the highest fresh weight of lettuce (34.93 g/plant), the seconds highest fresh weight were found in 60-24/0 (3 white LEDs -24 hours light/0 hour dark) treatments and 80-18/6 (2 purple LEDs – 18 hours light/6 hour dark) treatments (28.95 and 27.22 g/plant). The fresh weight varied depending on the red: blue intervals (Shimokawa et al., 2014). Besides, photosynthesis and photo morphogenesis were affected by light quality, light intensity and photoperiod (Cope *et al*., 2011). LED light intensity and photoperiod affected on the fresh weight of lettuce.

Table 6: Chlorophyll (µg/g) of hydroponic leaf lettuce grown under four LED light intensities combined with 5 different photoperiod regimes at 35 days

Photoperiod regimes (A)	LED light intensities (B)				Average
	1 purple	2 purple	3 white	3 purple	
6/18 (L/D)	1.31^{c}	1.40^{c}	1.35^{e}	1.25^{d}	1.33^{d}
9/15 (L/D)	2.02^{bc}	2.64^{b}	2.17^{d}	2.82^{c}	2.41^{c}
12/12 (L/D)	2.22^{abc}	3.07^{b}	2.76^{c}	3.77^{b}	2.56^{b}
18/6 (L/D)	3.27^{a}	4.04^{a}	4.11^{a}	4.75^{a}	4.04^{a}
24/0 (L/D)	3.06^{ab}	4.22^{a}	3.56^{b}	3.92^{ab}	3.69^{a}
Average	2.37^{C}	3.07^{AB}	2.79^{B}	3.30^{A}	
F (A):			**		
F (B):			**		
F (A*B):			**		
CV. (%):			10.03		

The values in each column followed by different normal characters and in each row followed by different capitalize characters are significantly different (Duncan test, P < 0.05)
*L/D: (light/dark). **: Significant at P ≤ 0.01*

The Chlorophyll values were found highly at 3 and 2 purple LED treatments (3.30 and 3.07 µg/g) and differed significantly with 1 purple LED and 3 white LED treatments (2.37 and 2.7 µg/g). The same result also was found in photoperiod factor, the highest chlorophyll values were found at 18/6 and 24/0 treatments (4.04 and 3.69 µg/g), and the lowest was at 6/18 treatment (1.33 µg/g). The in-

teraction among 18/6 and 24/0 treatments at 2 and 3 purple LED showed chlorophyll values higher than other treatments (except the interaction among 18/6 and 3 white LED treatments). The lowest chlorophyll values were found at interaction among 6/18 at four different light intensities (1.25-1.40 µg/g). This result was inconsistent with previous study (Kanget al., 2013). Chlorophyll is an extremely important molecule in photosynthesis which allows plants to absorb energy from light and it would affect on the growth and development of lettuce. Light intensity and photoperiod affected on lettuce's chlorophyll rate.

4 CONCLUSION

The interaction among 2 purple LED (80 µmol/m^2.s) at 18/6 and 24/0 (light/dark) treatments were better fresh weight, chlorophyll value, the leaf number, leaf length and leaf width of GN 63 lettuce than other treatments, while the highest length of main stem obtained at 3 white LED treatment with 24/0 treatments. LEDs could provide light source for hydroponic lettuce.

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