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Growth of Lettuce (*Lactucasativa* L.) Plant Under Red-Blue-White Light and Grow Light LEDs in Plant Factory System

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Abstract— *Indoor culture requires a variety of inputs to get maximum biomass. These inputs are the nutrients, temperature, humidity, and light which plants needed to photosynthesize. Different types of light have been studied and it is known that the same spectrum will give different responses by different plants. The purpose of this study was to find out the effect of red-blue-white light LED on lettuce growth compared to grow light LED as a control which commonly used in plant factory rooms. The red-blue-white light is arranged on a 100 cm long aluminum rod, mounted along the plant in a gully DFT hydroponic fed by 1000-2000 ppm nutrients of ABmix plus with a pH of 5.5-6.5. LED grow light provided the plant a significantly higher height of 16.30% compared to red-blue-white light, but was no different to the length of lettuce root. The number and the area of leaves in red-blue-white light were markedly higher at 16.67% and 33.78% respectively than grow light. In addition, the red-blue-white light increased the chlorophyll content, fresh weight, and dry weight of lettuce plants, by 25.00%, 101.49% and 58.13% consecutively. Therefore, these results suggested that the red-blue-white LED light provided a significant higher biomass than the grow light LED.*

Keywords— **plant factory, grow light LED, red-blue-white light LED, lettuce.**

I. INTRODUCTION

Foodstuffs, especially vegetables such as lettuce, is very useful for the health of the body. The vegetable should be produced close to consumers (in the city) to reduce transportation costs, but because of land limitation in urban areas, a new system is needed to grow indoor crops by utilizing technology so that products are cleaner and healthier, which we call such system is plant factory.

Plant factory requires various inputs such as nutrient solutions and other growing factors such as temperature, humidity, and light energy. Light bulbs are needed for plants to photosynthesize to produce biomasa. There has been a lot of research about the type of light spectrum with its combination to provide optimal intensity in spurring plant growth. According to Senger (1982), the same type of light will give a different mophogenesis response depending on plant species. Yorio *et al*. (2001) found that fluorescent cool-white light (CWF) is best light at spurring lettuce growth compared to red, blue, and green rays and their combinations.In contrast, Kim *et al*. (2004) showed different data, namely that red-blue LED lights with a 24% green supplement at wavelengths of 500-600 nm was most spur the growth of lettuce plants compared to all other types of combinations including CWF light. CWF is a light commonly used as a control of lights that are broad spectrum approaching to solar rays. Furthermore, Shimizu *et al*. (2011) showed that red monochromatic rays was best and markedly increased the fresh weight and dry weight of lettuce.Another study revealed that red-blue rays at a 4:1 ratio had the best effect on plant growth and chlorophyll leaf content compared to red-green-blue rays (Nguyen *et al*., 2021).Kobayashi *et al*. (2013) found that blue LED light rays stimulate vegetative growth and blue light spurs flowering.

In general, plants absorb spectrum rays at visible light wavelengths of 400-700 nm with concentrations in red and blue light. Plant chlorophyll absorbs unequal amounts of light energy to photosynthesize. Chlorophyll-a absorbs only blue-violet light (400-500 nm) and red light (650-700 nm) while chlorophyll-b requires only blue and orange spectrum (600-650 nm). Even a recent study conducted by Bugbee (2019) found that far red light was a light that can spur cell enlargement. Various types of rays and their combinations both in units of intensity, quality, energy, and wavelength in spurring plant growth are not yet known exactly. Therefore, research is needed on the use of red-blue-white LEDs light to know the comparison with grow light white LED. White grow light LEDs are lamps commonly used in plant factories that have been extensively researched.

II. MATERIALS AND METHODS

Materials and equipments

The materials used were the seedlings of the lettuce plant "Jonction RZ" in rock wool media, AB mix plus nutrient solution, pH lowering solution (nitric acid and phosphoric acid) and raw water. The equipments used were plant factory room, hydroponics system DFT (Deep Flow Technique), IoT System (which is able to show air humidity, room temperature, solution concentration, nutrient solution temperature, and able to regulate the pH of nutrient solution), white light LED polychromatic grow light (four spectrum peaks: λ = 450 nm, λ = 527-542 nm, λ = 608 nm, 54 watts), and red-blue-white combination LED lights with characteristic red light (λ=618 nm, 3 watts), blue (λ=452 nm, 2 watts), and white (λ=450 nm, λ=527-542 nm, λ=608 nm, 1 watt) (Figure 1).

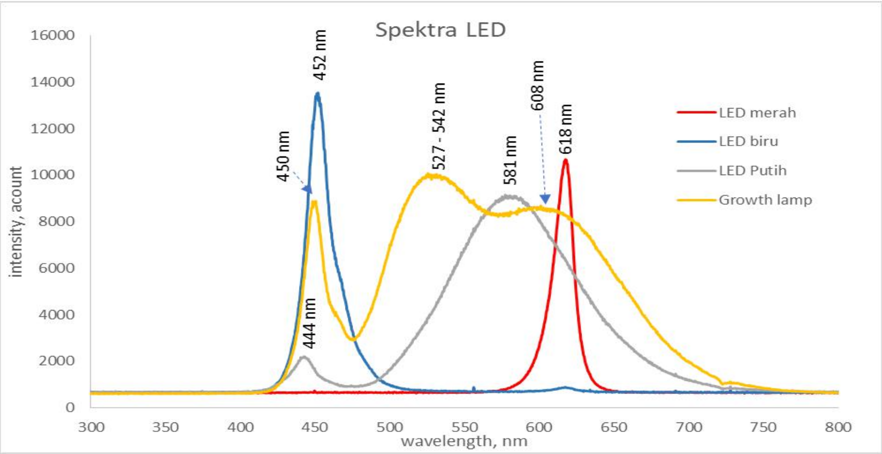

Fig.1: The spectrum of grow light LED and red-blue-white light LEDs were used in the study.

Seedling and planting

The seeds of *Lactuca sativa* L. cultivar "Jonction RZ" were immersed in rock wool with a size of 2 cm x 2 cm x 2 cm in a tray, then watered until saturated, covered with black plastic one night. Growing seedlings were then maintained and subjected to sunlight and watered every 2 days with a nutrient solution AB mix plus 500 ppm until two weeks old and transferred (transplanting) to gully in the DFT hydroponic system. The seedlingswere put into a net pot (basal diameter 3.5 cm, upper diameter 4.4 cm, height 5 cm) then placed in a gully hole with a distance of 20 cm.

LED light setup

The lights used in this experiment were grow light LED (Light Emitting Diode) lamp and a combined of red-blue-white light LED. Grow light LED lamp is a series of LED bulb with a total of 54 watts. Red-blue-white light LED lamp is a series of repeated 3 red bulb, 1 blue bulb, and 1 white bulb. The lampswere set along a hydroponic gully that was a total length of 3.6 meters. The lamp was turned on for 18 hours and then turned off for 6 hours intermittently as a photoperiodic for the process of photosynthesis and respiration of plants. The hydroponic system used was DFT (Deep Flow Technique) which has the advantage of water pooling as deep as 2 cm in gully that provides guarantees to plants still got nutrients even if the solution in gully stops flowing due to the pump damaged or the electricity went out. The DFT system scheme used in this study as Figure 2.

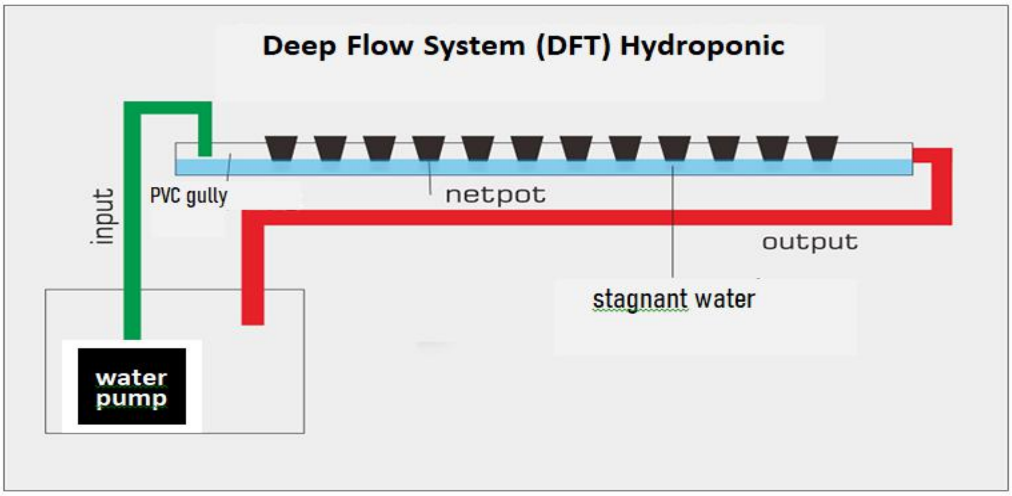

Fig.2: Scheme of deep flow system (DFT) hydroponic used in the plant factory. (Modified from: https://www.bing.com/images/search?view.)

Plant nutrient solution

The solution used to nourish plants was AB mix general vegetable containing macro and micro nutrients (Table 1) with the addition of Calcium nitrate (Ca(NO3)2) as much as 90 grams per literbased on method of Suryantini*et al*. (2019).

Table 1. Chemical contained onAB mix solution for vegetable general in onelitre

Description	Chemicals structure	Weight (g)	Concentration (ppm)	Group A/B
Calcium nitrate	$Ca(NO_3)_2$	138	235.4	A
Potasium nitrate	KNO_3	130.4	334.9	A
Monopothasiumphosphate	KH_2PO_4	34.5	87.1	B
Magnesium sulphate	$MgSO_4.7H_2O$	78.9	89.4	B
Amonium sulphate	$(NH_4)_2SO_4$	21.8	49.1	B
FeEDTA	$C_{10}H_{12}N_2O_8$ FeNa.3H_2O	3.08	2.03	A
FeEDDHA	$C_{18}H_{16}N_2O_6FeNa$	1.54	0.54	A
Boric acid	H_3BO_3	0.735	0.64	B
ZnEDTA	$C_{10}H_{14}MnNa_2O_8Zn$	0.186	0.13	B
MnEDTA	$C_{10}H_{14}MnN_2O_8$	0.988	0.64	B
CuEDTA	$C_{10}H_{14}CuN_2O_8$	0.096	0.07	B
Sodium molibdat	$Na_2MoO_4.2H_2O$	0.033	0.10	B

Observation variables

The observed plant variables were 1) plant height, measured from the base of the stem to the highest leaf end after being straightened up, 2) the length of the root, measured from the base of the stem down to the end of the root, 3) the number of leaves, calculated all the number of leaves present on the plant to the smallest leaves that can be counted, 4) fresh weight of the plant, measured by weighing the weight of the plant header using digital weighing equipment, 5) dry weight of the plant, measured the dry weight of the plant after drying in the oven with a temperature of 80°C until its weight was fixed, 5) the area of the leaves, measured by measuring the entire leaves of the observed plant,6) The amount of chlorophyll, done with the SPAD Units (Special Products Analysis Division Units). Each plant was measured three leaves and each leaf was measured in three parts, namely at the tip, middle, and the basal of the leaf, then averaged. All data was analyzed with a t-test of 5% as the indipenden group.

III. RESULTS AND DISCUSSIONS

Plant growth was observed weekly since the plant was transplanted (0 mst, weeks after transplanting) to 4 mst. Other variables namely fresh weight, dry weight, leaf area, and amount of chlorophyll were observed during harvest at 4 mst.

Plant height and plant root length

Lettuce plants in plant factorywere treated led grow light and red-blue-white LEDs with photoperiodic 18 hours of on lights and 6 hours off alternately. Lettuce plants that were exposed to a LED grow light exhibited the plant height every week higher than plants on red-blue-white LED lights (Table 2).The average height of plants in LED grow light was 15.7 cm,was markedly higher by 19.30% compared to plants illuminated by red-blue-white LED lights of13.16 cm. It was likely that plants experience mild ethiolation that occureddue to the intensity of grow light was low, allowing IAA growth hormone to be more active than the influence of red-blue-white light.Husen (2001) and Pacholczak*et al*. (2005) revealed that the presence of ethiolation will activate the IAA hormone that spured plant growth so that plants were higher, even the condition can also increase the number and length of roots on plant cuttings.

Although the LED grow light spectrum provided a more complete spectrum of between 420-750 nm with three peaks namely λ=450 nm, λ=527-542 nm, and λ=608 nm (Figure 1) but its intensity was low at about 9000 lux for blue light and 8500 lux for the red spectrum compared to the red-blue-white light with 13,500 lux for the blue spectrum and 10,000 lux for the red spectrum.

Table 2. The height of the lettuce plant on two different types of light bulbs

Light sources/colors	Weeks after transplanting (WAT)					
	0	1	2	3	4	Averages
LED grow light lamp (white)	5.25	8.41	17.40	21.10	26.35	15.70 a (19.30%)^z
LED red-blue-white lamp	5.23	6.47	14.00	17.50	22.60	13.16 b
Significance by t-test 5%,t_{count}=2.2798, t_{Table}=1.7341, ^{z}percentage of increase.						

The appearance of the lettuce plant at the age of 4 mst (weeks after transplanting) was presented in Figure 3 below.

Fig.3: Growth of lettuce plants. A) given a LED grow light: a. appears up, b. appears side; B) given a LED red-blue-white light: c. appears above, and d. appears side.

Number and areas of leaves

Lettuce leaves on red-blue-white LED lights every week were more leaves number than that exposed to led grow light (Table 3). The average number of leaves on a red-blue-white light (13.16 sheets) was 16.67% higher than in LED grow light (11.28 sheets). The plants at the red-blue-white light appear more lushes (Figure 3) and were supported by a much wider average leaf area of 2284.4

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cm^2 on red-blue-and-white LEDs and 1707.6 cm^2 on grow light LED (Table 4). Much higher growth in these red-blue-white LEDs than lettuce affected by grow light was due to the role of chlorophyll-a which absorbs blue light and chlorophyll-b absorbs red light which was of higher spectrum quality than the same spectrum in grow light rays (Figure 1). This was supported by Saeboet *al*. (1995) which states that red light can increase carbohydrate accumulation in the leaves by inhibiting the translocation of photosintat out of the leaves.

Blue and red light can increase biomass productivity, seed germination, plant stem growth (Parks *et al*., 2001), chlorophyll content when given green light supplements (Bian*et al*., 2018) in lettuce plants. Furthermore, Brown *et al*. (1995), found that red light (660 nm) requires a blue light supplement for chili plants to grow normally.

Table 3. Number of lettuce plant leaves on two different types of light lamps

Light sources/colors	Weeks after transplanting (WAT)					
	0	1	2	3	4	Averages
LED grow light lamp (white)	5.20	7.00	10.80	14.50	18.90	11.28 a
LED red-blue-white lamp	5.33	7.60	11.90	16.80	25.60	13.16 b (16.67%)^z

Significance byt-test 5%, t_{count}=2.7138,t_{Table}=1.7341, ^{z}percentage of increase.

Table 4. The area of plant leaves on two different types of light lamps

Light sources/colors	Plant-1 (cm^2)	Plant-2 (cm^2)	Plant-3 (cm^2)	Average (cm^2)
LED grow light lamp (white)	2099.09	1707.79	1315.79	1707.6 a
LED red-blue-white lamp	2931.32	2456.74	1465.12	2284.4 b (33.78%)^z

Significance by t-test 5%, t_{count}=2.7855,t_{table}=1.7341, ^{z}percentage of increase

Chlorophyll content, fresh weight, and dry weight of plant

Plant chlorophyll was measured by SPAD Units (Special Products Analysis Division Units). The amount of chlorophyll contained in grow light LED and red-blue-white LED differ markedly which were 18.2 SPAD and 22.8 SPAD, respectively. The amount of chlorophyll in leaves on red-blue-white LED lights was 25% higher than plants that exposed to grow light LED (Table 5). More chlorophyll in this treatment will support higher photosynthetic activity,thereafter the fresh weight and dry weight of the plant became greater. The fresh weight of the plantand the dry weight of the plant on the red-blue-white light treatment were greater significantly than the plants irradiated by grow light, respectively increased by 101.49% and58.13% (Tables 6 and 7). Thesewere supported by research conducted by Senger (1982) which stated that blue light spurs the formation of chlorophyll, the opening of stomata, and the formation of various enzymes involved in the process of photosynthesis. Blue light encourages the development of chloroplasts and increased in the amount of chlorophyll (Akoyunoglou and Anni, 1984) and when combined with red light (1:4) can markedly increased the amount of chlorophyll, fresh weight, and dry weight of spinach plants (Nguyen *et al*., 2021).

Table 5. The content of plant chlorophyll in two different types of lamps

Light sources/colors	Plant-1 (SPAD)	Plant-2 (SPAD)	Plant-3 (SPAD)	Averages (SPAD)
LED grow light lamp (white)	19.5	16.7	18.5	18.2 a
LED red-blue-white lamp	21.4	19.0	28.0	22.8 b (25%)^z

Significance by t-test 5%,t_{count}=2.2962; t_{table}=1.7341, ^{z}percentage of increase.

Table 6. Total plant fresh weight in two different types of lamps

Light sources/colors	Plant-1 (g)	Plant-2 (g)	Plant-3 (g)	Plant-4 (g)	Average (g)
LED grow light lamp (white)	77.01	83.03	54.02	57.01	67.77 a
LED red-blue-white lamp	187.20	182.00	77.00	100.01	136.55 b (101.49%)^{z}

Significance by t-test 5%, t_{count}=2.3668, t_{table}=0.7176, ^{z}percentage of increase.

Table 7. Total plant dry weightin two different types of lamps

Light sources/colors	Plant-1 (g)	Plant-2 (g)	Plant-3 (g)	Plant-4 (g)	Average (g)
LED grow light lamp (white)	4.12	2.23	3.11	3.34	3.20 a
LED red-blue-white lamp	8.23	3.33	3.43	5.24	5.06 b (58.13%)^{z}

Significance by t-test 5%, t_{count}=1.5362, t_{table}=0.7176, ^{z}percentage of increase.

IV. CONCLUSION AND SUGGESTION

Conclusion

LED grow light exhibited the lettuce plant a significantly higher height of 16.30% compared to red-blue-white LED light. On the other hand, the number of leaf and leaf area in red-blue-white light LEDweremuch higher, which were 16.67% and 33.78% respectively compared to grow light LED. In addition, the red-blue-white light LED increased the content of chlorophyll, fresh weight, and dry weight of lettuce plants by 25.00%, 101.49%, and 58.13%, consecutively. Red-blue-and-white LED light provided a higher biomass than grow light LED.

Suggestion

More detailed studies should be done on the effect of red-blue-white lights LED on the nutritional and phytochemical content of lettuce plants in plant factory.

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REFERENCES

[1] Akoyunoglou, G. and H. Anni. 1984. Blue light effect on chloroplast development in higher plant. In Blue light effects in biological systems. Springer, Berlin, Heidelberg.

[2] Bian, Z.,Q.Yang, T. Li, R. Cheng, Y. Barnett, C. Lu. 2018. Study of the beneficial effects of green light on lettuce grown under short-term continuous red and blue light-emitting diodes. Physiol. Plant. 2018, 164, 226-240. [CrossRef].

[3] Brown, C.S., A.C. Schuerger, J.C. Sager. 1995. Growth and photomorphogenesis of pepper plants under red LEDs with supplemental blue or far-red lighting. Journal of the American Society for Horticultural Science 120(5):808-813. DOI:10.21273/JASHS.120.5.808.

[4] Bugbee, B. 2019. Far red: The forgotten photons. https://advanced growlights.com/ far-red-the-forgotten-photons/. [20 October 2021].

[5] Husen, A., M. Pal. 2001. Interactive effect of auxin and etiolation on adventitious root formation in cuttings of *Tectona grandis* Linn. f. Ind. For. 127(5):526-532.

[6] Kim,Hyeon-Hye, Gregory D. Goins, Raymond M. Wheeler, John C. Sager. 2004. Green-light supplementation for enhanced lettuce growth under red- and blue-light-emitting diodes. HortScience39(7):1617-1622.

[7] Kobayashi, K., T. Amore, and M. Lazaro. 2013. Light-Emitting Diodes (LEDs) for miniature hydroponic lettuce. Honolulu, USA 3, 7477.

[8] Nguyen, Thi-Phuong-Dung, Dong-Cheol Jang, Thi-Thanh-Huyen Tran, Quang-Thach Nguyen. 2021. Influence of green light added with red and blue LEDs on the growth, leaf microstructure and quality of spinach (*Spinacia oleracea* L.). Agronomy 11(9):1724 DOI:10.3390/Agronomy11091724.

[9] Pacholczak, A., W. Szydło, A. Tukaszewska. 2005. Effectiveness of foliar auxin application to stock plants in rooting of stem cuttings of ornamentalshrubs. Propagation of Ornamental Plants 5(2):100-106.

[10] Parks, B.M., K.M. Folta, and E.P. Spalding. 2001. Photocontrol of stem growth.Current Opinion in Plant Biology 4:436-444.

[11] Saebo, A., T. Krekling, and M. Appelgren. 1995. Light quality affects photosynthesis and leaf anatomy of birch

plantlets in vitro. Plant Cell Tissue Organ Culture 41:177-185.

[12] Senger, H. 1982. The effect of blue light on plants andmicroorganisms. Photochemistry and Photobiology35:911-920.

[13] Shimizu, H., Yuta Saito, Hiroshi Nakashima, Juro Miyasaka, Katsuaki Ohdoi. 2011. Light environment optimization for lettuce growth in plant factory. Preprints of the 18th IFAC World Congress Milano (Italy) August 28-September 2, 2011.

[14] Suryantini, N.N., G. Wijana, R. Dwiyani. 2021. Pengaruhpenambahan $Ca(NO_3)_2$terhadaphasiltanamanseladakriting (*Lactuca sativa* L.) pada hidroponiksistem Deep Flow Technique (DFT). Agrotrop 10(2):190-200.

[15] Yorio, N. C. , G. D. Goins, H. R. Kagie, R. M. Wheeler, J. C. Sager. 2001. Improving spinach, radish, and lettuce growth under red light-emitting diodes (LEDs) with blue light supplementation. Hort Science36(2):380-383.