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The Effect of Light Emitting Diode (LED) White and Blue Spectrum on The Characteristics of Lettuce Grown in The Deep Flow Hydroponic

Yosua P. Sihotang[1], Indriyani[1], dan Dewi Fortuna[1]
[1]Agricultural Engineering Study Program, Faculty of Agriculture, University of Jambi, Jl Raya Jambi-Ma Bulian, Jambi, Indonesia

Email: indriyani@unja.ac.id

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Abstract :
Lettuce (*Lactuca sativa* L) is a promising horticultural crop with high economic value. This plant contains minerals, vitamins, antioxidants, potassium, iron, folate, carotene, vitamins C and E. The Deep Flow Technique (DFT) method has proven effective in growing lettuce hydroponically. This research used a randomized block design (RAK) to test the effect of giving lettuce plants white and blue LED spectrums. There were four treatments tested: P1 (no LED), P2 (1:3 white and blue LED), P3 (1:1 white and blue LED), and P4 (3:1 white and blue LED). Each treatment was repeated five times, with two sample plants in each repetition, so there were 40 sample plants. Measurements were carried out every week for five weeks. The results showed that LED lights significantly affected the number of leaves, stem diameter, root weight, and consumption weight but did not significantly affect plant height, leaf width, root length, antioxidant content, and leaf color. Based on this research, it can be concluded that treatment 4 (white and blue LED 3:1) gave the best results, with the number of leaves reaching 27.4 pieces, root length 18.95 cm, root weight 23.2 g, consumption weight 109 g, stem diameter 8.2 mm, and antioxidant content of 42.39% inhibition.

Keywords:Deep Flow Technique, Hidroponic, Light Emitting Diode, Lettuce

1. Introduction

In the field of horticulture, lettuce (*Lactuca sativa L*) is an attractive type of plant and has high economic value. This plant is rich in nutrients, including minerals, vitamins, antioxidants, potassium, iron, folate, carotene, vitamin C, and also vitamin E (Jahro, 2018). The nutritional content in lettuce has important benefits for body health. These nutrients, including vitamins and minerals, play a crucial role in the formation of red blood cells and white blood cells in the bone marrow. Apart from that, this nutrition can also reduce the risk of cancer, tumors and cataracts. Lettuce also has a positive impact on the digestive system and the health of organs around the liver, and helps overcome the problem of anemia (Jahro, 2018).

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Lettuce can be planted using the hydroponic method, which is a farming method that uses water and a mixture of nutrients as a plant growth medium. A good hydroponic system can supply water, nutrients and oxygen compounds to the root zone (Frasetya et al., 2021). Lettuce hydroponics can use the Deep Flow Technique (DFT) system. Plants are planted above channels that flow nutrient solution at a height of between 4 and 10 cm continuously. This nutrient solution is continuously circulated through the root area using a water pump (Arianto et al., 2020). The advantage of the DFT system is that if the pump stops running, the nutrient fluid will still remain in the pipe (Arianto et al., 2020).

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An important factor in the rate of photosynthesis is sunlight. Sunlight consists of white light which can be separated into various colors because it has different wavelengths. Sunlight has polychromatic properties, which means that if it is refracted, it will produce monochromatic light. This monochromatic light is received by chlorophyll and used in photosynthesis. The use of additional light instead of sunlight such as LEDs, fluorescent lights and incandescent lights has been used in plant cultivation, especially for lettuce (Johkan et al., 2010; Metallo et al., 2018).

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An LED lamp is an electronic device that is capable of producing a single colored light when a voltage is applied. Not all types of light can be absorbed by plants for the photosynthesis process. Some of the light used specifically by plants includes the white, red and blue spectrum (Patandean, 2021). LEDs have various advantages over traditional forms of horticultural lighting (Massa et al., 2008).

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2. Research Methods

Material

The materials used in this experiment included lettuce seeds, rock wool, AB Mix nutrients, electricity, and water. Meanwhile, the equipment includes PVC pipes, net pots, light steel, TDS meters, PH meters, water pumps, water boxes, water covers, LED lights, and long cables.

Research Design

This research used a Randomized Block Design (RBD) for the treatment of white and blue spectrum LEDs consisting of 4 treatments:

P1: Without LED.
P2: White: Blue LED (3:1)
P3: White: Blue LED (1:1)
P4: White: Blue LED (1:3)

Deep Flow Hydroponic Installation Technique and Light Emitting Diode

The hydroponic system used ten pipes with a diameter of 3 inches and a length of 200 cm. Each pipe is perforated at a distance of 20 cm, with ten holes in each pipe. In addition, the pipes are arranged in tiers vertically. Then, the white and blue spectrum LED lights are installed at the top of the hydroponic assembly.

The blue light waves produced range from 435-520 nm and require 18 watts of power. These three sets of LED lights will be installed at the top of the hydroponic system on the left and right of the system.

Sowing Lettuce Seeds

The rock wool is cut to size 2x2cm, and a hole is made at the top for placing the seeds. Put two seeds into the rock wool holes. Then the rockwool is placed on a tray and given water until the rockwool is wet (not flooded). Then, the tray is kept in a dark room without light for two days until the seeds sprout. After removing the shoots, the seeds are kept in the sun with the water monitored so they do not dry out. The sowing process continues until the seedlings are approximately 4 cm tall.

Transferring Seedlings to a Hydroponic System

The seeds that have been sown are transferred to the hydroponic planting hole by lifting the rock wool and placing them in the prepared net pot.

Providing Nutrition

The nutrient solution for AB Mix was made by mixing A (110 grams) and B (110 grams) in 500 mL of water each. The mixture of the two solutions is poured into 100 L of water and then stirred until evenly distributed. These nutrients are stored in plastic bottles. Suitable nutrient levels for lettuce plants are 560-840 ppm, measured using a TDS meter. Water acidity was measured with a pH meter, with a pH range of 6.0-7.0.

Nutrition Control

Nutrients were controlled using a TDS meter with 560 – 840 ppm (Arianto et al., 2020). In the first week, the nutrition provided was 560 ppm; in the second week, 600 ppm; in the third week, 700 ppm; and in the fourth week, 840 ppm. If the nutrient level decreases from the specified level, add another 5 mL of nutrient to the nutrient bucket and add 1 liter of water. The pH of the water was controlled using a pH meter in the pH range of 6.0 - 7.0.

Harvest

The lettuce harvested in the morning 35 days after planting starts with lifting the net pot from the planting hole. After the net pot is removed from the planting hole, the lettuce and rock wool are removed from the net pot. Then, after removing it, cut it at the base of the lettuce stem to separate the roots and rock wool from the lettuce stem and leaves. Lettuce leaves that have been harvested are immediately collected in a shady place to prevent the vegetables from drying out, wrinkling, and wilting in the sun.

Plant Height

The plant height of lettuce was measured from the base of the stem to the peak of growth on plant samples. Measurements were carried out every week at one-week intervals for five consecutive weeks.

Leaf Number

The leaf number was counted from the young leaf that had fully bloomed to the oldest leaf every week at one-week intervals for five consecutive weeks.

Root Length and weight

Lettuce was removed from the net pot, cleaned of adhering dirt, cut at the base of the roots, and measured length from base to tip after harvest. Then, it was weighed using a digital scale. These observations were carried out weekly for five consecutive weeks.

Consumption Weight

Weighing consumption is carried out at harvest time by removing the lettuce from the rock wool and then cutting at the base of the stem and the weight using a digital scale.

Leaf color

The healthy part of the leaf was cut, and the color was measured in the laboratory using a color reader to obtain L*, a*, and b* values. The °Hue value was calculated using the a* and b* values.

Leaf Width

The widest leaf is measured in width from left to right or vice versa after harvest. The leaf being measured was the third leaf from the plant's shoot.

Stem Diameter

The stem diameter measured at the bottom starts from 2 cm from the stem's base and then increases by 1 cm to 3 points. Measurements are taken only at harvest time.

Antioxidant Levels (DPPH Method)

The method is to take 0.2 mL of a sample using a micropipette and place it in a screw flask. Then, add 3.8 mL of 1.122 µM DPPH ethanol solution to the flask. The solution was stirred evenly and stored in the dark for 30 minutes at room temperature. After that, it was measured using a spectrophotometer at a wavelength of 517 nm. The antioxidant activity of samples can be calculated through inhibition calculations based on the magnitude of the inhibition of free radical uptake, which can be determined through inhibition calculations..

Data Analysis

The information collected will be processed statistically using the Analysis of Variance (Anova) technique. If the analysis results show a significant impact, the next step will involve Duncan's New Multiple Range Test (DNMRT) using SPSS software.

3. Result and Discussion

Plant Height

The use of LEDs with a white and blue spectrum does not have a significant effect on the height of lettuce plants. The best average plant height results were obtained in the treatment with white: blue LEDs (3:1), reaching 19.08 cm, while the lowest average results were seen in the treatment without LEDs, with a plant height of 17.07 cm. From the data above, it can be concluded that the large number of white spectrum LEDs provides excellent benefits for the height growth of lettuce plants, while plants without LEDs have the lowest height growth compared to plants that are given LED assistance.

Lighting influences the direction of root growth and unrotated leaf expansion. Leaf seek more sunlight to support photosynthesis. Lighting also causes growth to slow, causing the parts not exposed to light to become longer. Sunlight also affects the xylem's growth, ultimately affecting stem development. Besides photosynthesis, light also affects the growth of each organ and the entire plant. Dark conditions will affect the external shape of the plant and its growth rate (Maghfiroh, 2017).

Table 1. Increase in height of lettuce plants per week with the addition of LED lights

Treatment	Day after planting					
	1	8	15	22	29	35
Without LED	5.54	10.37	14.63	17.63	22.15	32.12
White: Blue LED (3:1)	5.63	10.97	16.45	19.97	25.02	36.48
White; Blue LED (1:1)	5.25	10.77	15.38	19.98	24.28	32.86
White: Blue LED (1:3)	5.09	11.05	16.36	21.44	25.12	33.06

Leaf Number

LED lights with a white and blue spectrum significantly influence the leaf's number of lettuce at harvest. The most lettuce leaf was recorded in the treatment using white: blue LED (3:1), with 80 leaves. Table 3 shows that the white: blue LED (3:1) treatment gave the highest average leaf number, 27.40 pieces. This figure is much higher than the white: blue LED (1:3) treatment, which only had 24.40 leaves, the white:

blue LED (1:1) with 19.50 leaves, and the treatment without LED with 20.80 leaves. Overall, the yield from each LED treatment showed significant differences compared to other treatments.

Table 2 shows that increasing the number of blue spectrum LEDs greatly benefits the growth of lettuce leaves. The color blue is perfect for plant growth. After all, chlorophyll absorbs blue light, allowing photosynthesis to run optimally (Prameswari, 2017). This research also confirms that light wavelengths in the visible color spectrum, with the longest and shortest wavelengths (Wiguna et al., 2015), significantly impact plant growth. External and internal factors, including the addition of LED light color, can also influence the number of leaves on plants. Besides the external environment's influence, leaf growth is also controlled by internal factors such as genetics and hormones.

Table 2. The Leaf number of lettuce with the addition of LED lights during 35 days after planting

Treatment	Day after planting					
	1	8	15	22	29	35
Without LED	4.0	6.7	8.8	14.5	16.0	20.8^{c}
White: Blue LED (3:1)	4.0	6.0	8.6	13.8	15.7	24.4^{b}
White; Blue LED (1:1)	5.5	5.8	8.2	11.6	15.4	19.5^{d}
White: Blue LED (1:3)	5.3	6.2	9.3	13.6	18.2	27.4^{a}

Note. Values in a column followed by the same letter are not significantly different ($p > 0.05$)

Root Length and Weight

LED lights with a white and blue spectrum do not significantly affect the root length of lettuce plants. The best average root length occurred when using white: blue LEDs (3:1), reaching 18.95 cm. The white: blue LED (1:1) produces a root length of around 17.57 cm, while the white: blue LED (1:3) reaches 15.58 cm. The treatment without LED produced the lowest root length, namely 14.43 cm. The observation results show that using white: blue led (3:1) LEDs provides optimal root length results compared to other settings in this study. Lettuce development is also influenced by root length, essential in absorbing dissolved nutrients to support its growth (Tiljuir et al., 2023). The difference in impact between each treatment may be because blue-spectrum LEDs are more effective in influencing root growth than white-spectrum LEDs. According to research (Novinanto & Setiawan, 2019), plants absorb red and blue light, which is important for plant growth because chlorophyll absorbs red and blue light, allowing photosynthesis to run optimally.

The use of LED lights with a white and blue spectrum significantly impacts the root weight of lettuce plants. The best average results were obtained from the white-blue LED (3:1), where the root weight reached 23.2 g—followed by the white: blue LED (1:3), which produced a root weight of 13.5 g, the white and blue LED (1:1) of 11.7 g, and the treatment without LED lights which produced the lowest root weight, namely 8. 3 g. Observation showed that using white: blue LED (3:1) produced optimal root weight compared to other treatments. The white: blue LED (3:1) treatment significantly differs from the other three treatments. However, the white: blue LED (1:3) and (1:1) did not significantly differ, although both significantly differed from the treatment without LED lights. Based on this research, it was found that the abundance of roots in plants is an indication of better plant growth. The more roots a plant has, the more optimal its growth will be (Torey et al., 2013). Plants meet their water needs by absorbing it through their roots. The presence of water in the soil and the ability of the roots to absorb it significantly influence the amount of water the roots can absorb. Therefore, roots' ability to absorb water significantly impacts root weight when wet (Safii, 2020).

Table 3. The root length of lettuce plants with the addition of LED lights at 35 days after planting

Treatment	Root Length (cm)	Root Weight (g)
Without LED	14.43 ± 0.82	8.3 ± 2.51 [c]
White: Blue LED (3:1)	15.58 ± 3.95	13.5 ± 5.20 [b]
White; Blue LED (1:1)	17.57 ± 1.50	11.7 ± 4.32 [b]
White: Blue LED (1:3)	18.95 ± 4.68	23.2± 7.80 [a]

Note. Values in a column followed by the same letter are not significantly different ($p > 0.05$)

Consumption Weight

LEDs with a white-blue spectrum significantly affect the consumption weight of lettuce plants. Based on the average results, giving LEDs with a white: blue LED (3:1) produces the best consumption weight of 109 g. then white: blue LED (1:3) with a consumption weight of 68.9 g, white: blue LED (1:1) with a consumption weight of 53.8 g, and treatment without LED with a consumption weight of 46 g. Research shows that giving LEDs with a white: blue LED (3:1) produces optimal consumption weight results compared to other treatments. The white: blue LED (3:1) treatment differed significantly from the other three treatments, while the white: blue LED (1:1) and without LED treatments did not show significant differences. However, both significantly differed from the white: blue LED (1:3) treatment. From this information, providing additional blue spectrum LED lights to lettuce plants results in better growth because the number of lettuce plant leaves is positively correlated with the weight of the plant consumed. The more leaves, the weight of lettuce plants also increases. Apart from that, good root growth also has a positive effect on the growth of other plant parts because the roots can absorb water and nutrients the plant needs. The consumption weight value of lettuce plants reflects how much photosynthesis results were accumulated in various parts of the plant. Therefore, adding blue spectrum LED lights can increase the growth results of lettuce plants (Abror & Prasetyo, 2018; Lutfiana et al., 2023).

Table 4. The consumption weight of lettuce plants with the addition of LED lights at 35 days after planting

Treatment	Consumption Weight (g)
Without LED	46±11.20 [a]
White: Blue LED (3:1)	68.9±24.17 [b]
White; Blue LED (1:1)	53.8±20.14 [a]
White: Blue LED (1:3)	109±40.54 [c]

Note. Values in a column followed by the same letter are not significantly different ($p > 0.05$)

Stem Diameter

The use of LED lights with a combination of white and blue significantly impacts the stem diameter of lettuce plants. The best average results were obtained using white: blue LED (3:1) around 8.199 mm. Meanwhile, using white: blue LED (1:3)resulted in a stem diameter of around 6.132 mm, and plants that did not receive exposure to LED lights had a stem diameter of around 5.166 mm. Treatment with white: blue LED (1:1) produced the smallest stem diameter, around 4.83 mm. Observation results show that using white: blue LED lights with a (3:1)provides optimal consumption results better than other treatments. This treatment is significantly different from the other three treatments. However, there was no significant difference between using white: blue LED (1:1) white-blue ratio and plants that did not receive exposure to LED lights. However, both were significantly different from using white: blue LED (1:3). Plant growth is influenced by one variable, and each variable will be interrelated to support growth and increase plant yields (Suryantini et al., 2020). This opinion aligns with the research results, where increasing the number of leaves, root length, root weight, and consumption weight obtained the best value in the white: blue LED (3:1) treatment. According to several other parameter data, the many superior results in the white: blue LED (3:1) treatment influenced the results of the stem diameter of lettuce.

Table 5. The stem diameter of lettuce plants with the addition of LED lights at 35 days after planting

Treatment	Diameter (mm)
Without LED	5.17 ± 0.97 [a]
White: Blue LED (3:1)	6.13 ± 0.97 [b]
White; Blue LED (1:1)	4.83 ± 0.93 [a]
White: Blue LED (1:3)	8.20 ± 1.63 [c]

Note. Values in a column followed by the same letter are not significantly different ($p > 0.05$)

Leaf Width

The use of LED lights that have a white and blue color spectrum has a significant impact on the size of lettuce plant leaves. In this experiment, the best average results for leaf width were found when using a combination of white: blue LED (1:1) of 12.34 cm. Meanwhile, white: blue LED (3:1) produces a leaf width of around 12.31 cm. These results were better than the treatment without LEDs, which produced a leaf width of around 11.35 cm, and the white: blue LED (1:3) produced a leaf width of around 11.31 cm. From these observations, it can be concluded that using a white: blue LED (1:1) combination provides optimal leaf width results. However, there is no significant difference when using white: blue LED (3:1). However, this result differed from the treatment without LEDs and using white: blue LED (1:3), resulting in lower leaf width. The photosynthesis process is closely related to the area of leaves produced by lettuce plants; the widest leaves indicate that the photosynthesis process in the plant is running optimally. According to Pertamawati (2010), photosynthesis would be optimal if the leaves, which are the leading site of the photosynthesis process, were more significant.

Table 6. The Leaf width of lettuce plant leaves with the addition of LED lights at 35 days after planting

Treatment	Leaf Width (cm)
Without LED	11.35 ± 0.72 [a]
White: Blue LED (3:1)	11.31 ± 1.44 [a]
White; Blue LED (1:1)	12.34 ± 0.93 [b]
White: Blue LED (1:3)	12.31 ± 1.02 [b]

Note. Values in a column followed by the same letter are not significantly different ($p > 0.05$)

Leaf Color

Lettuce leaf color analysis involves measuring the components L*, a*, and b*, which describe color characteristics. Color reader devices are used to identify these colors. The L* value reflects the brightness level from 0 (black) to 100 (white). The a value indicates a red-green color mixture, with the +a* value indicating red (0-100) and the -a* value indicating green (0-(-80)). Meanwhile, the b* value reflects a mixture of blue-yellow colors, with the +b* value indicating yellow (0-70) and the -b* value indicating blue (0-(-70)).

Based on Table 7, it can be concluded that adding white and blue spectrum LEDs does not significantly impact the L*, a*, b*, and our color values. The average L* values recorded ranged from 54.52 to 57.96. The L* value scale ranges from 0 (dark) to 100 (light) and indicates the brightness level of reflected light, which creates the achromatic colors white, gray, and black (Murib & Kartikawati, 2022). The a* value was negative in the range from -9.4 to -10.36. The -a* values from 0 to -80 indicate green, according to research by Murib & Kartikawati (2022). The result is a lettuce color that tends towards green. The resulting b* value reflects a mixture of blue-yellow chromatic colors ranging from 26.80 to 28.80. The +b* value range from 0 to +70 indicates yellow (Murib & Kartikawati, 2022). Therefore, the results of these values indicate that the color of the lettuce produced is yellow. The °Hue value for lettuce leaves is between 159.33 to 159.91. The value range in the description of lettuce leaf color is Yellow-green. All treatments that have been carried out produce leaf color in the yellow to greenish-yellow color scale.

Table 7. Average values of L*, a*, b*, and °Hue of lettuce leaf color when LED lights are added at 35 days after planting

Color	L*	a*	b*	°Hue	Color	Description	Color Code (hex color)
No Light	55.66 ± 1.33	-9.40 ± 0.64	26.80 ± 0.62	159.91 ± 1.54		Dark yellow green	#868956
White 3:1 Blue	57.96 ± 2.15	-9.76 ± 1.04	27.48 ± 3.83	159.49 ± 2.46		Dark yellow green	#8c8f5b
White 1:1 Blue	54.52 ± 1.32	-10.36 ± 0.76	28.80 ± 2.51	159.33 ± 2.80		Dark yellow green	#828650
White 1:3 Blue	56.86 ± 4.88	-9.74 ± 1.42	27.66 ± 4.29	159.53 ± 3.05		Dark yellow green	#898c58

Antioxidant Activity

Radical capture methods involve measuring artificial free radicals that appear in polar organic solvents, such as methanol, at room temperature. This process utilizes antioxidant compounds to overcome these free radicals. In this method, the DPPH compound is used as a marker. DPPH will interact with antioxidant compounds by taking hydrogen atoms, forming new electron pairs due to the reaction (Cholisoh & Utami, 2008). The DPPH method has advantages in terms of convenience, speed, and sensitivity. However, this method also has some drawbacks. One drawback is that it needs to provide more information about the activity of the compound being tested. In addition, this method can only measure compounds that act as antioxidants and can dissolve in certain organic solvents, especially alcohol (Utomo et al., 2013).

Table 8. Antioxidant activity of lettuce plants when LED lights are added at 35 days after planting

Treatment	% Inhibition
Without LED	38.59±6.65
White: Blue LED (3:1)	38.52± 5.49
White; Blue LED (1:1)	38.34± 9.62
White: Blue LED (1:3)	42.39± 10.07

Table 8 shows that the influence of the light spectrum and length of exposure using LEDs resulted in the most significant average antioxidant levels in the white: blue LED (3:1) had 42.39% inhibition. Followed by treatment without LED, it got a level of 38.59% inhibition. The white: blue LED (1:3) had 38.52% inhibition, and the lowest was the white: blue LED (1:1) had 38.34% inhibition. Blue light involves various plant processes, such as phototropism, photomorphogenesis, stomatal opening, and photosynthesis (Whitelam & Halliday, 2007). Most studies with blue light alone or a mixture of blue and red light show that irradiation containing blue light produces higher plant biomass (Matsuda et al., 2008). The light spectrum also stimulates the biosynthesis of phenolic compounds. Blue light induces the accumulation of flavonoids (Ebisawa et al., 2008; Kojima et al., 2010) and anthocyanins, which are one class of flavonoid compounds, play a role in antioxidant activity (Duan et al., 2007). Planting seeds irradiated with blue light can increase crop yields after planting due to the high accumulation of phenolic compounds (Johkan et al., 2010).

Conclusion

The use of LED lights has a significant impact on leaf number, stem size, root weight, and plant consumption. However, using these lights does not significantly affect plant height, leaf width, root length, antioxidant content, and leaf color. The best comparison of white: blue spectrum LEDs on DFT hydroponic lettuce was obtained in the white: blue LED (3:1). This treatment obtained the best results in the number of leaves with the highest number of 27.4, root length of 18.95 cm, root weight of 23.2 g, consumption weight of 109 g, stem diameter of 8.2 mm, and antioxidant content of 42.39 % inhibition.

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