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Performance Test of LED Grow Light with Indoor Hydroponic System for Horticultural Plants

Uji Kinerja Lampu LED Grow Light dengan Sistem Hidroponik Indoor untuk Tanaman Hortikultura

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ABSTRACT

This study aimed to evaluate the performance of LED grow lights in an indoor hydroponic system for horticultural plants. The problem identified was the need for energy efficiency and optimal yield in hydroponic growth systems. The experimental research method involved collecting descriptive data presented in tables and figures. Variables measured included power consumption, light intensity, temperature, humidity, plant height, leaf count, leaf width, and pH and EC levels. The results showed that lettuce (*Lactuca sativa* L.) grown with a 25-watt LED grow light in a wick hydroponic system exhibited the best growth compared to lower power levels. The highest productivity was achieved under 12 hours of sunlight, yielding 17.82 tons/ha, while 20 hours of LED lighting resulted in the lowest productivity at 7.11 tons/ha. A 16-hour lighting treatment produced better results, with a yield of 11.05 tons/ha. In conclusion, the duration and type of lighting significantly affect lettuce productivity in a hydroponic system.

Keywords: Cultivation Indoor; LEDs Grow Light; Lettuce Plant; Wick Hydroponics

ABSTRAK

Penelitian ini bertujuan untuk menguji kinerja lampu LED grow light dengan sistem hidroponik indoor pada tanaman hortikultura. Identifikasi masalah berkaitan dengan kebutuhan efisiensi energi dan hasil optimal pada sistem pertumbuhan hidroponik. Metode yang digunakan adalah penelitian eksperimental, di mana data dikumpulkan secara deskriptif dalam bentuk tabel dan gambar. Beberapa variabel yang diukur meliputi kebutuhan daya, intensitas cahaya, suhu, kelembaban, tinggi tanaman, jumlah daun, lebar daun, serta pengukuran pH dan EC. Hasil penelitian menunjukkan bahwa selada (Lactuca sativa L.) yang menggunakan lampu LED grow light 25 watt dengan sistem hidroponik sumbu memiliki pertumbuhan terbaik dibandingkan daya yang lebih rendah. Produktivitas tertinggi tercapai pada tanaman yang terkena sinar matahari selama 12 jam, yaitu sebesar 17,82 ton/ha, sedangkan penyinaran lampu LED selama 20 jam menghasilkan produktivitas terkecil sebesar 7,11 ton/ha. Penyinaran selama 16 jam menunjukkan hasil yang lebih baik dengan produktivitas 11,05 ton/ha. Kesimpulannya, durasi dan jenis pencahayaan mempengaruhi hasil produktivitas selada dalam sistem hidroponik.

Kata kunci: *Budidaya Indoor; Hidroponik Sumbu; LED Grow Light; Tanaman Selada*

INTRODUCTION

The condition of agricultural land in Indonesia is decreasing along with the increasing demand for food, especially vegetable crops. Urban farming has emerged as a potential solution to overcome these challenges, particularly in urban areas, by providing an alternative method for producing clean, pesticide-free vegetables like lettuce (Payen et al., 2022). While existing studies have explored the benefits of urban farming in various contexts, there is a lack of research that specifically examines the effectiveness of LED grow lights combined with indoor hydroponic systems for horticultural crops in Indonesia. This study seeks to fill that gap by evaluating the performance of LED grow lights in optimizing vegetable production, with a focus on key environmental factors such as temperature, humidity, and pH, which are critical for plant growth (Zhai et al., 2020). One technology that can be used is the hydroponic system. It allows plants to grow without nutrient-rich soil (Sambo et al., 2019).

Hydroponics is a method of growing plants in water containing a nutrient mixture. This system uses non-soil growing media such as sand and husk charcoal to support plant growth. There are many types of hydroponics, including wick system hydroponics (Kamalia et al., 2017). The advantages of the wick hydroponic system are that it is easy to maintain, safe from disease and rain, the risk of being attacked by pests is small, it does not require a large area of land, and it can increase growth in plants (Morrow, 2008).

Conventional vegetable cultivation faces several challenges, including the amount of land available. Every year, the amount of agricultural land decreases due to converting agricultural land to residential buildings and offices, so crop cultivation is done indoors (Anindyarasmi et al., 2021). In indoor plant cultivation, light intensity is essential to plant growth because light plays a vital role in photosynthesis. Low light intensity can cause plants to not grow properly (Maftukhah et al., 2023). This can be done with LED (Light Emitting Diode) growing light intensity to meet the light needs of these plants. The advantage of using this type of LED light is that the light spectrum is small, the power consumption is lower than incandescent and fluorescent lights, and LED grow lights produce low heat compared to other lights (Novinanto & Andree, 2019).

Plants cannot absorb all colors of light produced by lamps. Red and blue are the colors of light that plants can absorb because chlorophyll absorbs these colors of light, so photosynthesis runs optimally and is suitable for plant growth (Pennisi et al., 2019). LED grow light irradiation with hydroponics can increase the productivity of lettuce plants (Nguyen et al., 2022). Lettuce plants can grow optimally with sufficient light intensity and the quality of light that plants need. LED grow lights can meet the light color quality and intensity required by lettuce plants (Putra et al., 2016).

The rapid development of technology has solved many problems, including artificial lighting, such as LED (Light Emitting Diode) grow lights. Based on this background, a performance test of LED grow lights with an indoor hydroponic system for agro-industrial plants was conducted.

METHODOLOGY

Tools and Materials

The equipment used to test the performance of an LED grow light with an indoor hydroponic system for agro-industrial plants are 25 watts LED grow light 6 pieces, a timer, hydroponic tray, net pot, digital scale, AC power meter, lux meter, camera, plastic, stationery, water quality tester, DC fan, planting box, and thermohygrometer.

Materials used were caipira lettuce seeds, water, rock wool, and AB mix hydroponic nutrients

Prosedur Penelitian

This research was conducted from December 2023 to January 2024 at the Laboratory of Agricultural Energy Biosystems and Drafting, Department of Agricultural Technology, Faculty of Agriculture, Sriwijaya University and Permata Indralaya Hydroponics. The method used is an experimental method with data presented descriptively in the form of figures and tables. The research was conducted by designing, observing, and analyzing data. Research analysis includes LED grow light irradiation for 16 hours of observation (A), using LED grow light irradiation for 20 hours of observation (B), and using sunlight as a control plant (in the greenhouse) for 12 hours (C).

Power Requirements (W)

Power requirements are measured directly using an AC power meter. The equation used to calculate power requirements is as follows (Faridha et al., 2016):

$$P = V x I \quad (1)$$

Description:
P = Power (watts)
V = Voltage (volt)
I = Electric current (ampere)

Electrical Energy (kWh)

The results of electrical energy measurements were carried out once during the plant growth process using LED grow lights. The measuring instrument used to measure electrical energy is an AC power meter. The equation used to calculate electrical energy is as follows (Wahid & Mukhlison, 2019):

$$E = P \times t \quad (2)$$

Description:
E = Electrical Energy (kWh)
P = Power (watt)
t = Time (hour)

Light Intensity (Lux)

Light intensity is measured once a week during the growth process of lettuce plants; light intensity is used as a photosynthesis process (Rosyida et al., 2022). The measuring instrument used to measure light intensity is a lux meter.

Temperature (°C)

Temperature observations were made daily for 35 days of research, and temperature measurements were made to measure the room temperature in the planting box. The optimal temperature for pakcoy plant growth ranges from 15-30°C (Sulistyowati & Nurhasanah, 2021). The measuring instrument used to measure temperature is a thermohygrometer.

Humidity (%)

Plant growth is affected by humidity. If the humidity of the environment is outside the limit, it will disrupt plant growth, so humidity observations were made every day for 35 days of research. Usually, pakcoy plants need humidity around 80%-90% (Hakim et al., 2019). The tool used to measure humidity is a Thermohygrometer (Amalia et al., 2020).

Measurement of Solution pH

pH measurement is used to determine the acidic or basic content of the solution measured on a scale of 0 to 14 (Rahmani et al., 2021). These observations were made once a week for 35 days of research. The pH of the solution was measured using a water quality tester.

EC (Electrical Conductivity)

EC measurements are taken once a week until the 35-day observation process. According to Firdaus & Furqon (2021), This measurement is carried out to preserve plants' nutritional needs so that they can be of good quality. The tool used to measure EC is a water quality tester.

RESULTS AND DISCUSSION

Power Requirements (W)

The observations and calculations show the power requirements of lamp A (LED grow light 16 hours) and lamp B (LED grow light 20 hours) are 28.08 watts; there are differences in the measurement results of power requirements between AC power meters and manual calculations. This is because the Power factor (PF) value can affect the value of power requirements. A low power factor increases the supply voltage, so the current increases and lowers the power factor. According to Lisiani et al. (2019), the more significant the power factor is, the smaller the current flowing, and vice versa. If the power factor is small, the current flowing becomes large.

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Table 1. Observation and Measurement of Power Requirements (Watt)

Lamp Type	Voltage	Electric Current (Ampere)	PF (*Power Factor*)	Power (Watt)
Lamp A	216	0.13	0,90	25.27
Lamp B	216	0.13	0.90	25.27
DC Fan	12.47	0.18	-	2.24

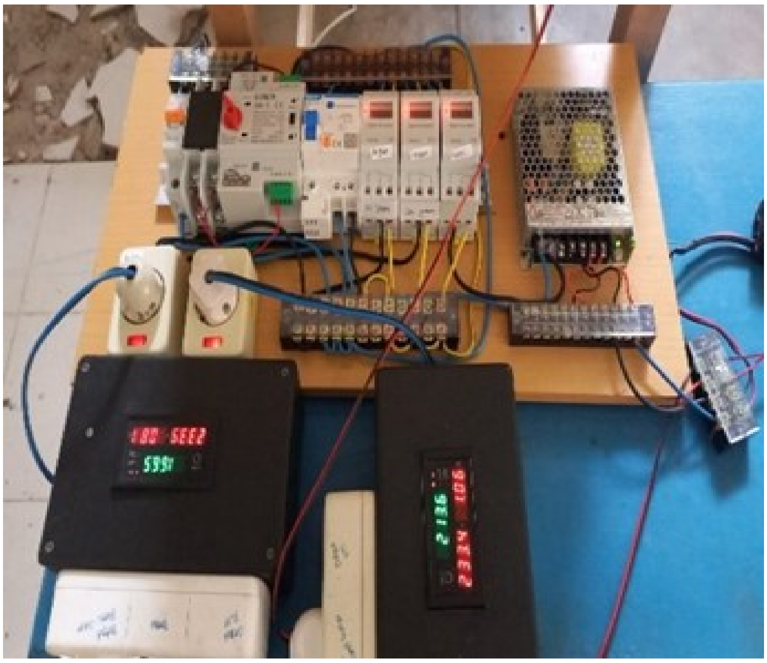

Figure 1. Power Requirement Measurement

The power requirement based on the calculation results in Table 1 using the AC power meter tool is 25.27 watts for lamp A (LED grow light 16 hours) and lamp B (LED grow light 20 hours), because it is influenced by the Power Factor (PF) value. Measurement with a DC fan produces a power factor of 2.24 watts for 16 hours of irradiation and 20 hours of irradiation. The difference in Power Factor between LED grow light and DC fan occurs due to different load characteristics and power conversion. LED grow lights usually have a higher PF due to the electrical power source that converts AC current into DC current and is often equipped with power factor correction, whereas DC fans use direct DC components without complex conversion processes and power factor correction, so their PF is lower (Cheng et al., 2021). The power requirement measurement can be seen in Figure 1.

Electrical Energy (kWh)

The results of electrical energy measurements based on Table 2 show that the 16-hour LED grow light (Lamp A) produces lower power, which is 14.15 kWh, while the 20-hour LED grow light (Lamp B) produces higher power, which is 17.69 kWh.

Table 2. Measurement of Electrical Energy

Treatment	Power (W)	Time (hour)	Electrical Energy (kWh)
Lamp A	25.27	16 hours/day x 35 day	14.15
Lamp B	25.27	20 hours/day x 35 day	17.69
DC Fan	2.24	21 hours/day x 35 day	1.65

Lamp A, 16 hours/day of irradiation, produces the most efficient electrical energy and the largest irradiance compared to lamp B, 20 hours/day. This is due to the optimal irradiation duration of lamp A, which maximizes energy efficiency by reducing unnecessary operating time. This efficiency may also be due to the difference in lamp settings, which allows lamp A to work more effectively for less time, reducing total power consumption while providing optimal lighting levels for plant growth (Singh et al., 2015). DC fans produce lower electrical energy of 1.65 kWh than LED grow lights because LED grow lights have more power than the power used by DC fans (Deng et al., 2017).

Light Intensity (Lux)

Based on the results of LED grow light intensity measurements in Table 3, the average value of total light intensity is calculated from the total amount of light intensity in three replicates and then divided by the number of replicates. Measurement of light intensity obtained lamp power of 25.27 watts produces light intensity in the week after planting, namely the age of 1 WAT long irradiation 16 hours (Lamp A) with an average of 9520.67 lux and irradiation 20 hours (Lamp B) with an average of 9216.00 lux, but the average total intensity obtained is too high, because the distance between the lamp and the plant tray is too close, this makes lettuce plants aged 1 WAT slow down the growth process and lettuce leaves become wilted.

Table 3. Light intensity measurement of LED grow light

Treatment	Plant Age	Replay			Total Number	Total Average
		1	2	3		
Lamp A	1 WAT	9453	9713	9396	28562.00	9520.67
	2 WAT	5938	5118	5554	16610.00	5536.67
	3 WAT	5434	5595	5586	16615.00	5538.33
	4 WAT	5051	5365	5446	15862.00	5287.33
	5 WAT	5274	5136	5226	15636.00	5212.00
Lamp B	1 WAT	9263	9142	9243	27648.00	9216.00
	2 WAT	5426	5091	5136	15653.00	5217.67
	3 WAT	5613	5450	5433	16496.00	5498.67
	4 WAT	5460	5379	5142	15981.00	5327.00
	5 WAT	5316	5075	5643	16034.00	5344.67

The growth of lettuce plants from 2 weeks to 5 weeks increased every week until harvest. The measurement results of total light intensity in the treatment of 16 hours of irradiation (Lamp A) are 5536.67 lux to 5212.00 lux, and in the treatment of 20 hours of irradiation (Lamp B) are 5217.67 lux to 5344.67 lux.

The results of light intensity measurements on control plants in the afternoon from 1 WAT to 5 WAT amounted to 5169 lux to 5732 lux, which shows the growth of lettuce plants outside the box is increasing every week compared to the development of lettuce plants in the box, due to differences in light intensity in the morning, afternoon, and evening. According to Pamungkas et al. (2015), The required sunlight intensity for lettuce plant growth is 2152.78-4305.56 lux. Treatment plants (A), treatment (B), and control plants produce high light intensity but good lettuce plant growth weekly. Measurement of the light intensity of the LED grow light can be seen in Figure 2.

Figure 2. Light Intensity Measurement

Temperature (°C)

The optimum air temperature for lettuce growth is 25°C to 28°C. Temperature has a significant influence on lettuce growth, both morphologically and physiologically. If the temperature is below 25°C and exceeds the air temperature of 28°C, the photosynthesis process is not optimal (Supriyanto et al., 2022).

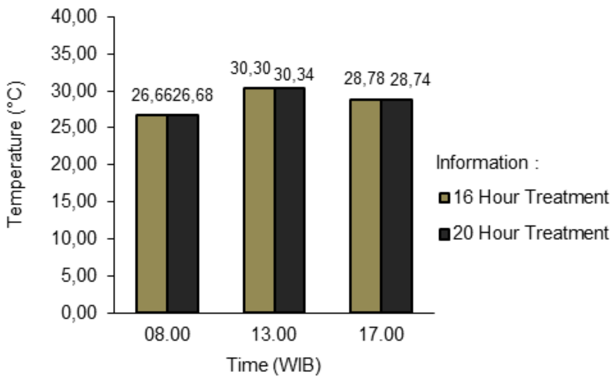

Figure 3. Average Daily Temperature

Based on the results of temperature measurements in Figure 3, it is found that the temperature is lower in the treatment of 16 hours of irradiation compared to 20 hours of irradiation. This is because the 20-hour irradiation time takes longer to perform the irradiation process using LED grow light lamps for lettuce growth compared to the 16-hour irradiation time. The temperature of the control plants was taken from BMKG data showing the average daily temperature during the 35 days of research from December 19, 2023 to January 29, 2024 (Suhairi & Tuzsakdiah, 2023).

Humidity (% RH)

Based on the observations shown in Figure 4, the 16-hour irradiation treatment has the highest average value of humidity compared to the 20-hour irradiation. This is because temperature and humidity affect each other.

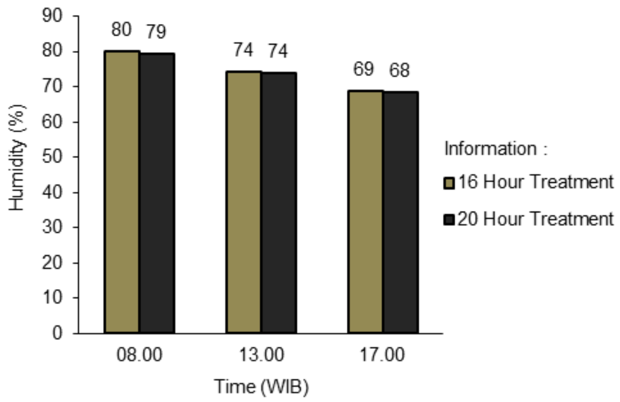

Figure 4. Average Daily Humidity

The average temperature of the 16-hour irradiation period is lower than the 20-hour irradiation period, but the humidity is higher when compared to the 20-hour irradiation period. This occurs because the 20-hour irradiation period takes longer when performing the LED grow light irradiation process on lettuce growth. Hence, the average temperature is higher, and the humidity is low. Humidity in control plants is taken from BMKG data, which shows the average daily humidity during the 35 research processes. According to Mangkusasmito et al. (2023), lettuce growth is optimal at 60-80% humidity.

Measurement of Solution pH and EC (Electrical Conductivity)

pH Solution

Treatment A (LED grow light 16 hours) and treatment B (LED grow light 20 hours) showed pH observations ranging from 6.0-7.0 from the age of 1 WAT to 5 WAT. The weekly pH in control plants (C) showed 6.0-7.0. If the pH value drops below 6.0 or above 7.0, then a nutrient solution must be added to return the pH to the ideal range for the absorption of plant nutrients (Wati & Walidatush, 2021).

EC (Electrical Conductivity) (μS/cm)

Treatment A (LED grow light 16 hours) and treatment B (LED grow light 20 hours), as well as sunlight as a control plant (C), showed observation results at 1 WAT ranging from 1000 μS/cm to 1200 μS/cm, at 2 WAT and 3 WAT ranging from 1200 μS/cm to 1800 μS/cm, and at 4 WAT to 5 WAT ranging from 1800 μS/cm to 2200 μS/cm. According to Gabriela & Koesriharti (2022), the nutrients needed by lettuce plants do not have the same EC value; this depends on the age of the lettuce, so for optimal results, there is a specific EC value according to the age of the lettuce.

Plant Growth

Measurements of height, number of leaves, and leaf width of lettuce plants can be seen in Table 4. According to Eliaser et al. (2023), Plant growth is influenced by the environment, such as nutrition; this can be observed by observing age, light, and balance, such as pH and EC. According to El Khair & Rian (2020), lamp distance and plants significantly affect growth. At the age of 1 WAT, the temperature is too high. The humidity is low, causing obstacles in plant growth because at the age of 1 WAT using bricks, the distance between the lamp and the tray is only 20 cm, which inhibits the plant growth process, but at the age of 2 WAT without bricks. Hence, the distance between the lamp and the tray is 38 cm, increasing lettuce plants' growth every week until harvest.

Table 4. Plant growth measurement results

Treatment	Plant Age	Average Growth of Lettuce Plants		
		Plant Height (cm)	Number of Leaves (strands)	Leaf Width (cm)
Lamp A	1 WAT	5.35	4	2.15
	2 WAT	8.53	5	2.69
	3 WAT	9.47	5	4.59
	4 WAT	13.95	9	8.53
	5 WAT	16.45	11	10.09
Lamp B	1 WAT	5.65	5	2.17
	2 WAT	7.95	5	3.09
	3 WAT	8.83	5	3.93
	4 WAT	12.97	8	7.36
	5 WAT	15.36	10	9.58

Measurement of the height of lettuce plants from 1 WAT to 5 WAT showed an increase every week. In the 16-hour irradiation treatment, lettuce plants grew faster, with an average height of 5.35 cm to 16.45 cm, while in the 20-hour irradiation treatment, lettuce plants grew faster, with an average height of 5.65 cm to 15.36 cm. However, lettuce plant height growth is faster when using sunlight.

According to Rizal (2017), The increase in plant height produces more and more plant stems so that the leaves that grow on the stem also grow. According to Tripama & Muhammad Rizal Yahya (2018), forming plant leaf organs requires large amounts of nitrogen. The higher the nutrient solution concentration, the more leaves the plant produces. In this case, the 16-hour irradiation treatment has the highest average number of leaves, namely 4 leaves-11 leaves, compared to the 20-hour irradiation treatment, namely 5 leaves-10 leaves. Compared to the control plants, the average number of leaves is also the highest in the 16-hour irradiation treatment because there are pests on lettuce leaves outside the planting box, so plants in the box have the advantage of not being exposed to pests or viruses that interfere with the growth of lettuce plants (Ramitum et al., 2022).

The results of leaf width measurements found that 16 hours of irradiation has a greater average leaf width of 2.15 cm to 10.09 cm, compared to 20 hours of irradiation of 2.17 cm to 9.58 cm, but when compared outside the planting box with sunlight, the average leaf width of lettuce plants is greater than the treatment of 16 hours of irradiation because sunlight provides a complete spectrum of light and intensity that is more by the photosynthetic needs of plants, resulting in more ideal conditions for growth and greater leaf width (Miao et al., 2023).

Effect of Duration of Illumination

The growth of lettuce plants tended to be better with 16 hours of LED grow light (A) compared to 20 hours of LED grow light (B), but when compared to control plants with 12 hours of sunlight (C), the growth of lettuce plants was even faster than 16 hours of LED grow light (A).

Table 5. Effect of lamp irradiation duration on plant productivity

Duration of Illumination	Total Plant Fresh Weight (g)	Crop Productivity (tons/ha)
Lamp A (16 jam)	240,4	11,05
Lamp B (20 jam)	154,8	7,12
Control C (12 jam)	129,2	17,82

From the observations in Table 5 that the length of irradiation and light intensity affect the growth rate of plants. Lettuce growth with indoor cultivation is better than growth outside the planting box. This is influenced by pests on lettuce leaves that make lettuce plants unable to grow healthy (Díaz et al., 2010).

CONCLUSION

The research results conclude that LED grow light with 16 hours of irradiation (A) produces lamp light intensity of 5536.67 lux to 5212.00 lux, and with 20 hours of irradiation (B), producing lamp light intensity of 5217.67 lux to 5344.67 lux, with the intensity of the light produces good growth of lettuce plants during the growth process. The measurement results of the electrical energy needs of treatment A (LED grow light 16 hours) are lower at 14.15 kWh compared to treatment B (LED grow light 20 hours), which is 17.69 kWh. Lower electrical energy produces better plant productivity than high electrical energy. The productivity of lettuce plants was highest in the control plants that used sunlight for 12 hours, which was 17.82 tons/ha, and lowest in the treatment of 20 hours of irradiation (B), which was 7.11 tons/ha. Still, when compared in the planting box, 16 hours of irradiation (A) was higher, 11.05 tons/ha, compared to 20 hours of irradiation (B). These findings suggest that extending LED grow light exposure beyond 16 hours does not significantly improve plant growth, while increasing energy consumption. Therefore, using 16 hours of LED light irradiation is more energy-efficient and productive for lettuce cultivation. Future research could explore further optimizations in light spectrum and plant varieties to improve both yield and energy efficiency.

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