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Investigation on Light-Emitting Diode Indoor Grow Light for Lettuce Plant Growth

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Abstract: Indoor planting is new urban farming in this era but the lighting source is important for plant growth healthy. Thus, an artificial light from lamps is used to replace sunlight to assist plant growth. The disadvantage of outdoor planting is the weather condition is unpredictable causing limited or stunted plant growth. Other than that, the risk of plating outdoors is that pests attack may cause plant damage. The purpose of this research is to design a light-emitting diode (LED) grow light panel and develop a prototype of indoor planting using LED light growth and compare the condition of the lettuce salad if using LED grow light instead of sunlight as a lighting source. In this investigation, calculations on the electricity bills of automation grow light system and the energy consumption was also carried out. Meanwhile, the automatic LED grow lights were created by using real-time clock (RTC) modules for the lights feeding automatically to indoor farming from 6 am to 10 pm for a continuous 16 hours with an Arduino as a controller. From this investigation, data was collected every 10 days. The data shows that the value of 10 leaves and 14 cm in height for the red LED grow light while 7 leaves and 10 cm in height for the blue LED grow light on the 30th day. From the result, the indoor plant can grow efficiently because there is no risk of plant damage. In addition, low electricity bills were obtained which is RM1.06 /month for the LED light energy consumption. It can be concluded that the LED growth light can produce healthier plant products in terms of the leaf growth and plant height of lettuce hydroponic if compared to sunlight.

Keywords: RTC Module, Hydroponic, LED Grow Light, Arduino, Lettuce

1. Introduction

Indoor farming has allowed ordinary people anywhere to grow their own fruits and vegetables at home. Traditional agricultural methods such as producing crops on land are soon becoming useless. Indoor farming makes use of cutting-edge technology to grow more crops in less space. Outdoor farming uses natural sunlight for plants, while other forms of indoor farming use artificial lighting.

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Light from lamps used as a substitute for sunlight to assist plant growth must be of sufficient quality to meet the needs of the plants. Each source of light has a different quality of light. The white spectrum is the artificial light spectrum that most closely resembles the spectrum of sunlight. The blue and red or grow light colour combination is a more efficient substitute for the white colour spectrum for plant photosynthesis with the pigment chlorophyll [1].

LEDs are light-emitting diodes, which transform power into light by generating photons using the characteristics of metals. The emission of blue wavelengths is responsible for the white light produced by LED lights [2]. The blue wavelengths, for example, strike a phosphor coating on the bulb's glass, which emits yellow wavelengths of light. LEDs made it feasible to adjust the spectral quality in ways that were previously impossible with traditional electric light sources. LEDs are being used to investigate the role and significance of light quality, as well as the potential to regulate plant growth and development [3].

Scientists validated their findings through experiments, concluding that red and blue light has the greatest effects on plant development. The photo reversibility of red and infrared light was discovered around this time, demonstrating the relevance of the red and blue parts of the spectrum, according to Snowden's findings [4]. Spindly, elongated, and curled leaves result from the red zone, whereas compact growth and flat expansion of leaves emerge from the blue region [5].

2. Results and Discussion

2.1 System Implementation

A hydroponic wick system with automated LED grow lamps is implemented in Figure 1. The graphic provides an overview of the lighting conditions by showing LED grow lights installed above the lettuce plants. Wick hydroponic systems deliver nutrients to a plant's nutrient tank using a wick in a plant pot. Indoors, when the light from the LED grow light takes the place of sunlight, the use of LED grow light on the wick of the hydroponic system is employed. The LED grow light will start operating at 6:00 AM and end at 10:00 PM.

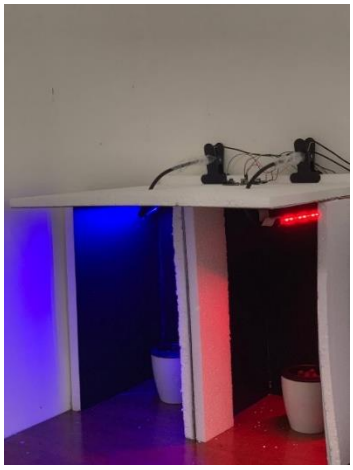

Figure 1: The prototype of the LED grow lights automation

Figure 2 shows the device implementation for a wick hydroponic system with LED grow lights automation. The hardware consists of Arduino and RTC module. The Arduino and RTC are then connected to the power outlets and LED grow lights to do control functions based on Arduino coding command.

Figure 2: Top view of the prototype that's shows the hardware system

2.2 Test Result For Lettuce Growth

Figure 3 shows the condition of the lettuce salad in 10 days after nursery phase and the lettuce seedling have been transfer to hydroponic pot. From Figure 3 below the condition of the lettuce under red and blue LED grow light are grow healthy. Meanwhile, the condition of the lettuce under sunlight somewhat stunted due to the weather factor that week was erratic and always rainy so the lettuce didn't get enough lighting.

Figure 3: The growth of the lettuce in 10 days

After 20 days, the lettuce was checked and added more nutrient solution which is fertiliser A and fertiliser B because the salad had grown bigger. Figure 4 shows the growth rate of the lettuce after 20 days. The condition of the lettuce is become healthier and there's some different between the three conditions of the lettuce. Under the blue LED grow light, the lettuce leaves look fat and a bit withered while under the red light the lettuce looks healthier and grows tall and the leaves look fresh. In another hand, the lettuce condition under the sunlight looks healthier than last 10 days but the lettuce is getting riskier because planting outdoor are expose to animals and pests.

After 30 days the lettuce waiting for the time to be harvested. Figure 5 shows the condition of the lettuce growth after 30 days. The condition of the lettuce growth under the blue lights looks strong, durable and crunchy as in previous research said that blue lights provide chlorophyll production which is good for photosynthesis [6].

Figure 4: The growth of the lettuce after 20 days

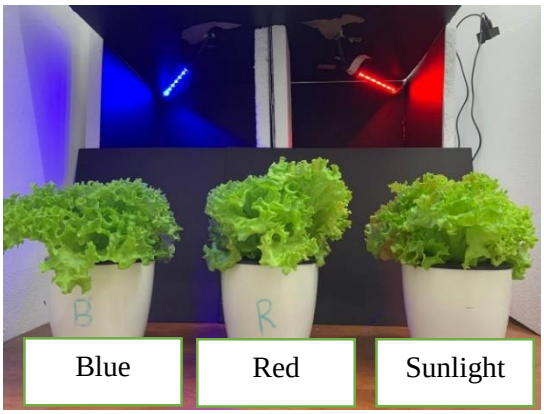

Figure 5: The growth of the lettuce after 30 days

Meanwhile the lettuce growth for red LED grow lights, grow height and healthy than lettuce under blue grow light but the leaves of lettuce thinner than leaves of the lettuce under blue LED grow light. Other than the good side of the red LED grow lights there also have risk when the lettuce grow height. In this situation the distance between the grow light and lettuce became near and may cause a tip burn that has been shown in Figure 6.

Figure 6: Tip burn on lettuce in red LED grow light

Besides that, after 30 days lettuce that receive sunlight growth healthy and strong compares to the grow light as it receives a full spectrum of lights. However, this outdoor plant is contaminated by animals and pests. Animals such as cats or monkeys play in the surrounding house area will cause plant damaged. Other than that, air pollution will also interfere with the cleanliness of the lettuce.

2.3 Data of number of leaves and plant height measurement

Lettuce salad hydroponic wick system is planted for 30 days. A ratio of 1000ml of water: 5ml A:5ml B is used to blend AB mix nutrients and water to create hydroponics. Based on measurements of plant height, number of leaves, and fresh plant weight, hydroponics growth is compared with two condition of LED grow light automation system and natural sunlight.

The lettuce chart in Figure 7 compares the quantity of hydroponically grown lettuce leaves produced under LED grow lights and in the presence of natural light over the course of 30 days. Hydroponics with blue and red LED grow lights generated 5 to7 leaves on the tenth day, while hydroponics with sunlight produced 4 to 5 leaves. Hydroponic systems with red LED grow lights generated 8 to10 leaves on the 20th day and blue LED grow light generated 5 to 7 leaves, whereas those with sunlight produced 10 to 12 leaves. Hydroponics with red LED grow lights produced 10 to 13 leaves and blue LED grow light produced 7 to 10 leaves on average on the 30th day. The hydroponics with sunlight, which the salad growth between 8 and 11 leaves. This investigation shows that the grow light can replaced the sunlight as the quality of the indoor salads are quite similar to the sunlight plants.

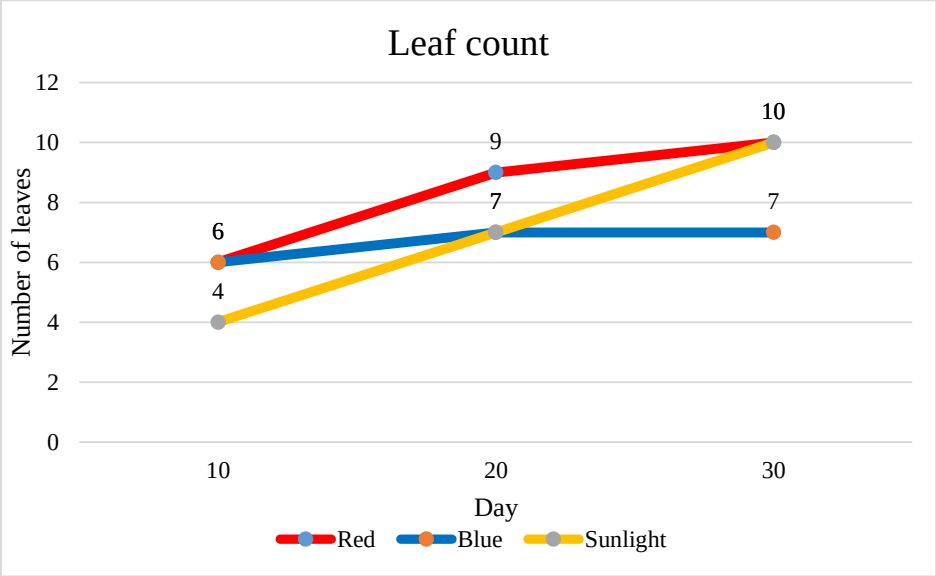

Figure 7: Number of leaves comparison of red and blue LED grow light and sunlight

The hydroponic lettuce plant height under LED growing light and sunlight is compared in the lettuce salad plot chart in Figure 4.11 for a period of 30 days, every 10 days. On day 10, hydroponics using red LED grow lights yields plants that are 8.5 cm tall and blue LED grow light growth 4.5 cm tall, whereas hydroponics using sunlight yields plants that are 4.5 cm tall same as blue LED grow light. On day 20, hydroponics with red LED growing lights generates plants with a height of 10 cm and blue LED grow light growth in 10 cm tall. Meanwhile, sunlight lettuce growth in 10.5 cm tall. After 30 days, the lettuce has reached maturity and ready to be harvest. The height has been recorded red LED grow light height is 14cm tall and blue LED grow light height is 10 cm while the sunlight exposure lettuce height is 11.5cm.

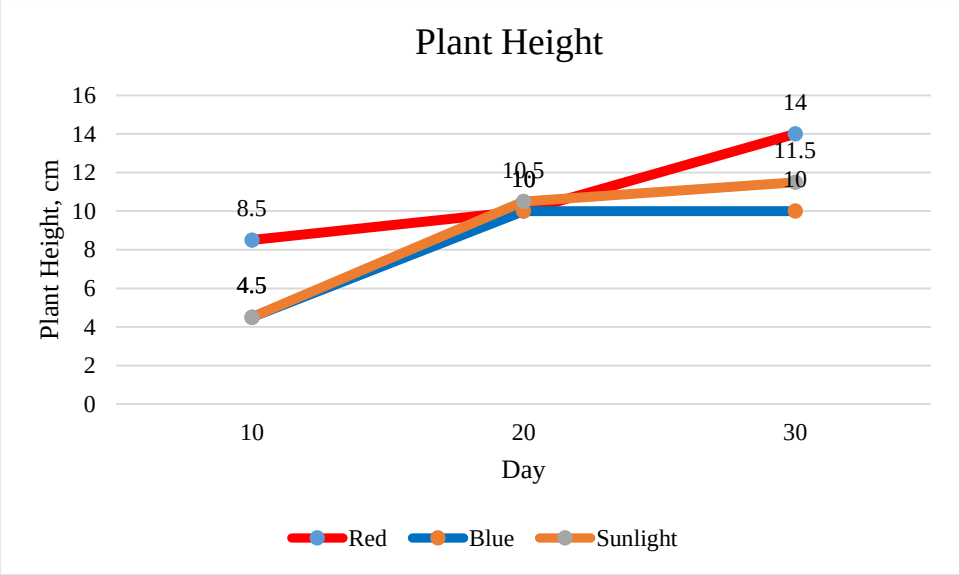

Figure 8: comparison of plant height of red and blue LED grow light and sunlight

2.4 Load Analysis

The automation grows light system's total load analysis for investigation on LED indoor grow light for lettuce plant is shown in Table 1. The total load analysis is necessary for system design. The estimated power consumption of the LED was determined using the specification of the prototype's automated grow light. The Arduino Uno's output voltage is 5V, meanwhile the LED strips' output current is 10W for both colour red and blue. Based on equation used the formula P=IV, the estimated power (W) is determined. The voltage is 5V and 2A for the current. The calculated power is 10W.

Table 1: Load Analysis of the system

No	Load	Qty	Estimated power, (W)	Operating time (h)	Daily energy Consumption (Wh)
1	Red LED	1	10	16	160
2	Blue LED	1	10	16	160
	Total energy consumption (W)				**320**

Calculating the electricity bills is necessary to estimate the energy consumption of the load using on grow light daily, monthly and yearly. The energy consumption can be used in order to calculate the electricity bills estimation in monthly and yearly. Based on My TNB website the latest electricity cost was in June 2022 which is for homes and enterprises, the cost of electricity is RM 0.221 per kWh, which includes all fees associated with electricity use, distribution, and taxes.

Table 2 shows the electricity bills estimation for monthly and yearly for one plant. The table shows one plant spent RM1.06 for monthly and RM 12.72 for yearly. This shows that grow light are the most economical for the future investment on selling vegetables. In this investigation LED have been using for the energy saving. LED are more efficient and provide good-quality light. LED are the least wattage usage in this case the least the wattage, the least the electricity bills.

Table 2: Electricity bills estimation for monthly and yearly for one plant

Electricity bill usage per month	Electricity bills usage per year
RM 1.06	RM 12.72

3. Conclusion

Based on the previous research and analysis done for this project, the conclusion was reached that using blue and red LED grow light for indoor planting could growth a healthy and fresh vegetables and effective to do an indoor farming for making a fresh and healthy vegetables supply. There a specific benefit for each colour of grow light, The main benefit of red light for plants is that it improves photosynthesis, which promotes growth and results in bigger, heavier plants. This project is to compare the performance of the growth rate of the lettuce salad plant by three condition of the light source which are sunlight and two colours of LED grow lights. The LED grow light was evaluated in two conditions which are the red LED grow light and blue LED grow light. The result shows differences of growth rate by investigating the plant height and the number of leaves. The results demonstrated that different colours of grow light will give different output. Chapter 4 provides all of the investigation results and the system of the automation LED grow light system. The graph of count leaf against days, plant height against days have been plotted to demonstrate the comparison in output every 10 days of the three condition of lighting sources that have been applied in hydroponics system. Results show that the red LED grow light indoor planting had a best lighting source for lettuce plant with 10 number of leaves and 14 cm plant height. However, lettuce with sunlight source have the same number of leaves but planting outdoor was risky caused of the animals and pests.

Acknowledgement

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