Comparison of Photosynthetic Active Radiation and Power Consumption Values of Different Wavelengths of LED Lamps for Vegetable Production

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Abstract**:** *Photosynthetic active radiation (µmol $m^{-2}s^{-1}$) (PAR) is defined as a radiation that remains between 400-700 nm wavelength and directly affects photosynthesis, and therefore, on plant growth. Light emitting diodes (LEDs) are PN (Positive, Negative) diodes with special additives that convert electrical energy into light energy when voltage is applied in the correct direction. Therefore, while the energy saving is achieved with the LED lighting lamps used in vegetable production, the most suitable PAR values can be given to the plant. In this work, the values of PAR of 1W and 3W LEDs, which are in red, day light, blue, orange, green and white color were measured for condition A and condition B based on CIE-2007 standard. Randomized block design with 3 replications was applied. The results showed that LED color x power interaction was significant in terms of PAR (P<0.01). For both conditions, among the 1W LEDs, the highest PAR values was determined for the red colored LED while the lowest PAR values was determined for green and orange colored LEDs. The similar trend was observed for 3W LEDs. Finally, an economical efficiency increase can be achieved in vegetable production with LED lamps.*

Keywords: *Photosynthetic active radiation, wavelengths, power consumption, vegetable production.*

1. Introduction

Light energy is one of the most important inputs of agricultural production. Light sources are divided into natural and artificial. While the light from the sun is expressed as natural light, the light emitted from artificial lighting sources is defined as artificial light. Light sources such as fluorescent lamps, metal halide lamps and LEDs are examples of artificial light sources [1]. When the tension is applied in the right direction; namely PN (Positive, Negative) diodes with special additive material that convert electrical energy into light energy. The fact that LEDs have superior characteristics compared to conventional lighting systems is a reason for their use in this work. In agricultural production, the time, duration and amount of illumination are affected by direct yield. PAR value is important in terms of plant growth and development. PAR can be defined as the amount of photons of light in the 400-700 nm wavelength range. For this reason, PAR measurements are also expressed in the form of photosynthetic photon flux density measurement.

Yeh and Chung (2009) noted that LEDs have a very long use time of 100,000 hours compared to fluorescent lamps with a lifespan of about 8000 hours. In addition, the LEDs have a small, fixed wavelength range and a low and adjustable light intensity and quality compared to conventional light sources. Because of these properties, LEDs are excellent light sources for controlled plant growth environments such as tissue culture and growth chambers.

Berkovich et al., (2005) reported that artificial lighting conditions are the best way to determine the response of plants to light.

Brazaityte et al. (2009) grew cucumber transplants in phytotrons and the recommended light spectrum included blue, red, PAR red, green and orange light. Leaves acclimate their photosystem composition to the growth light spectrum, which also suggests that a combination of different wavelengths can substantially enhance quantum yields [5]. In this work, LED light sources with different wavelengths, PAR values were measured using the CIE 2007 standard.

2. Material and Method

This research was carried out in the research laboratory of Süleyman Demirel University, Faculty of Agriculture, Agricultural Machinery Department. The research material is composed of different color (wavelength) and strong LED light sources. LED light sources in blue, white, orange, warm white, red and green color at 1 and 3 W in the direction of work purposes have been selected. A test method was developed to determine the PAR values of the LEDs selected for use in the study according to the CIE 127-2007 standard [6]. The test equipment used in the study is given in Figure 1.

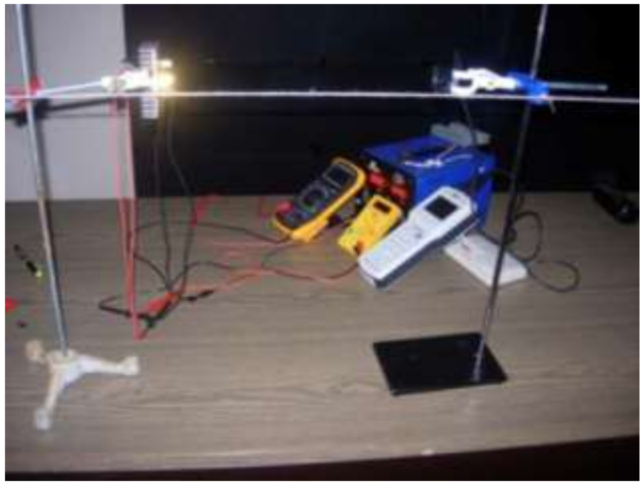

Fig 1: Test method used to determine the PAR values of the LEDs

The test equipment consists of a PAR sensor (Figure 2.), LEDs and two measurement stands. For measurements according to CIE 127-2007 standard, the mutual position of the distance between the PAR sensor and the LED must be adjusted. For this reason, two laboratory type measuring stands have been used to position the PAR sensor and LED. PAR measurements were performed in a laboratory environment where complete darkness (0 μmol m-2s-1) was achieved.

Fig 2: Photosynthetic active radiation sensor (LP 471PHOTO, DELTA OHM)

PAR measurements were performed according to the "condition A" and "condition B" cases in the CIE standard. The measurement of PAR values was given a schematic representation in Figure 3.

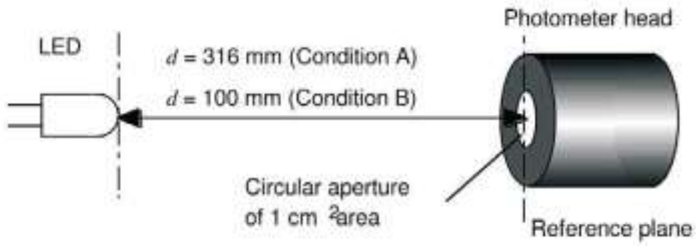

Fig 3: Geometry for CIE averaged LED intensity

In the relevant standard, the distance between the sensor and the PAR measured LED is given as 316 mm for condition A and 100 mm for condition B. The surface area of the PAR sensor is arranged to have a circular opening of 100 mm2 (Fig. 3). In order to be able to measure the PAR of the LEDs, both current and voltage values are read with two multimeters at the same time, and the LEDs are operated in sequence under optimum operating conditions determined by the manufacturer company. For PAR measurements of 1W and 3W LEDs, the multimeter was waited until the values of 350mA and 700mA were fixed, respectively. Then, PAR measurements were made on conditions that completely dark environment was created. During experiment, no current changes were made. PAR measurements were made when the current and voltage values read in the digital multimeters connected to the circuit are closest to the catalog values of the LEDs. The power is calculated by using the current and voltage values measured in the circuit. No light entered during measurement and the LED remained at the optimum temperature during the experiment. An aluminum cooler plate provides temperature control of the LED. In the experiment, the LEDs (1 Watt and 3 Watt) in blue, white, orange, warm white, red and green colors were made in 3 repetitions to measure PAR values. The data were analyzed for "condition A" and " condition B" by factorial straight variance analysis technique. The determination of the mean difference between the groups 'Tukey test' is used.

3. Result and Discussion

Two different powers for ‘condition A’ (G1, (1W) and G3, (3W)) and 6 different colors (LED1 (Red), LED2 (White), LED3 (Blue), LED4 (Green), LED5 (Orange), LED6 (Warm white)) PAR measurement results of the LEDs are given in Table 1. The PAR values of the LEDs in the 1W power range ranged from 2,207±0,039 to 0,752±0,050 μmol m^{-2} s^{-1}, while the 3W power values ranged from 5,443±0,351 to 1,305±0,051 μmol m^{-2} s^{-1} (Table 1).

TABLE I: Measured PAR Values of LEDs According to CIE 2007 Condition A

	PAR Values (μmol m^{-2} s^{-1})	
	G1 (1W LED)	G3 (3W LED)
LED1 (Red)	2,207±0,039Ab	5,443±0,351Aa
LED2 (White)	1,955±0,029ABb	3,243±0,213Ba
LED3 (Blue)	1,735±0,022Cb	3,240±0,071Ba
LED4 (Green)	0,822±0,012Cb	1,725±0,013Da
LED5 (Orange)	0,752±0,050Cb	1,305±0,051Da
LED6 (Warm White)	1,631±0,017Bb	2,543±0,082Ca

* The uppercase letters show the difference between the colors in each power, the lowercase letters show the difference between the powers in each color.

LEDs with both 1W and 3W power levels have the highest PAR values in red while the lowest PAR values are found in orange. This is thought to be due to the fact that the PAR sensors are more sensitive to the red color [7].

Two different powers for ‘condition B’ (G1, (1W) and G3, (3W)) and 6 different colors (LED1 (Red), LED2 (White), LED3 (Blue), LED4 (Green), LED5 Orange), LED6 (Warm white)) PAR measurement results of the LEDs are given in Table 2.

TABLE II: Measured PAR Values of LEDs According to CIE 2007 Condition B

	PAR Values (μmol m^{-2} s^{-1})	
	G1 (1W LED)	G3 (3W LED)
LED1 (Red)	22,933±0,203Ab	58,030±3,340Aa
LED2 (White)	20,057±0,284ABb	33,800±1,930Ba
LED3 (Blue)	17,840±0,284ABb	33,767±0,674Ba
LED4 (Green)	7,683±0,320Cb	17,547±0,224Da
LED5 (Orange)	9,807±0,500Cb	15,770±0,189Da
LED6 (Warm White)	16,447±0,106Bb	26,200±0,569Ca

* The uppercase letters show the difference between the colors in each power, the lowercase letters show the difference between the powers in each color.

The PAR values of the LEDs in the 1W power range ranged from 22,933±0,203 to 7,683±0,320 μmol m^{-2} s^{-1}, while the values at 3 W power ranged from 58,030±3,340 to 15,770±0,189 μmol m^{-2} s^{-1} (Table 2). The lowest PAR value was found for the green LED while the highest PAR value was determined for the red LED in the 1W power LEDs being measured. It is determined that there is a similar situation for LEDs in 3 W power.

4. Acknowledgements

In this study, the PAR values of the LEDs in 1 and 3 W power blue, white, orange, warm white, red and green colors were determined. For the LEDs in the measured 1W power, the highest PAR value was found for red, the lowest PAR value for orange and green LEDs. It is determined that there is a similar situation for LEDs in 3 W power. As a result of analysis of variance in terms of PAR characteristics, the color × power interaction was found statistically significant ($P < 0.01$). Finally it has been determined that red light is suitable for sustainable agriculture for artificial lighting studies for crop production.

5. References

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