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The Effects of LED Red, Blue, and White Light Colors Proportion on Chlorophyll Content and Canopy Area of Pakcoy (Brassica rapa L.)

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Abstract

Light is the main energy source for plants for the photosynthesis process. In indoor cultivation systems (plant factories), LEDs can be used as artificial light. The dominant light colors absorbed by plants for the photosynthesis process are red and blue, but the proportion of the LED colors used is unknown, so it is necessary to research the proportions of light colors. This study aims to determine the effect of the proportions of red, blue, and white light on the chlorophyll content (SPAD value) and the canopy area of Pakcoy. Pakcoy was planted in a growth chamber and given seven different proportions of light for 12 hours with a lamp total of 60 Watt and light intensity of 2000 lux. This study was conducted for 49 days, and the observations to make once a week. The results showed the proportion of red, blue, and white LED light treatment affects the chlorophyll content and canopy area. The proportions of LED light 30 Watt red, 20 Watt blue, and 10 Watt white produced the highest chlorophyll content (35.0 SPAD value) and canopy area (70.7 cm2). In conclusion, the proportion of red, blue, and white LED light showed significantly different in the growth of Pakcoy.

Keywords: *canopy area, chlorophyll content, LED light proportion, Pakcoy*

INTRODUCTION

Pakcoy (*Brassica rapa* L.) contains proteins, fats, carbohydrates, Ca, P, Fe, vitamins A, B, and C, which are very good for health (Haryanto *et al.*, 2006). In addition to the nutritional content, minerals, and vitamins, green leafy vegetables such as Pakcoy are also a source of chlorophyll which is beneficial for the human body (Wenno and Sinay, 2019). Chlorophyll is the green substance in leaves that is found in the green parts of plants, especially the leaves.The surrounding natural conditions can influence the content of chlorophyll in plants. Factors affecting the chlorophyll content include light intensity, temperature, and soil conditions (Nio Song and Banyo, 2011).

The increasing conversion of agricultural land currently makes Indonesia's agricultural land area continues to decrease. Badan Pusat Statistik (2018) records that around 60,000 hectares of land have been converted to non-agricultural land every year. This matter causes lower food production land so other alternatives are needed to overcome this problem. The indoor cultivation system or plant factory is one of the technologies that can overcome the problems of external environmental conditions and space utilization for agricultural cultivation (Nugroho, 2019). The concept of a plant factory is to build a facility in the form of an environment, which can be easily regulated and controlled according to growth needs. All growth factors such as light, temperature, water, carbon dioxide levels, humidity, and nutrition are regulated with technology, so its always available for plant growth (Kwon *et al.*, 2014). When using a plant factory, plants are not optimal for absorbing sunlight during the photosynthetic process, so artificial light are required to manipulate the sunlight. The artificial light used for cultivation must have good and appropriate quality, so plants can to properly perform photosynthetic processes to absorb the solar energy used for photosynthesis (Wanita and Afriani, 2020). In the process of photosynthesis, chlorophyll can absorb red (600-700 nm) to blue (400-500 nm) wavelengths, so lights designed for plant growth are similar to these waves (Poincelot, 1980). The content of chlorophyll is influenced by the canopy area. The wider the leaves, the total chlorophyll content will also increase (Ajiningrum, 2019).

The use of LED lights (Light Emitting Diode) can be used as a tool for manipulating sunlight (Morrow, 2008). LED lights are capable of emitting light that can be used for the photosynthesis process (Lindawati *et al.*, 2015). Blue light absorbs a lot of

plants in the vegetative phase and red light is absorbed a lot in the generative phase for the photosynthesis process (Soeleman and Donor, 2013). LED lights can be an alternative lighting source for hydroponically grown lettuce (Kobayashi *et al.*, 2013). Spectrum of monochromatic blue LED light (BB) and combination of red, blue or green light (RB and RBG) promote potato growth in vitro (Chen *et al.*, 2020). Monochromatic red and blue lights produce higher sensitivity (Bayat *et al.*, 2018). The combination of red, blue, and white LEDs have many a positive effects on the growth, development, nutrition, appearance, and quality of lettuce plants (Lin *et al.*, 2013) and have a positive effect on the growth process and productivity of Pakcoy (Sigmarawan *et al.*, 2020). But there are not many studies that mention the proportion of thr light. The purpose of this study was to determine the effect of red, blue, and white LED light on the chlorophyll content and canopy areas of the Pakcoy.

MATERIALS AND METHOD

Place and Time of Research

This research was conducted at the Greenhouse Laboratory of Agricultural Engineering Management System, Faculty of Agricultural Technology, Udayana University, from June 2021 until August 2021.

Materials

The tools used in this study included a growth chamber measured 60 cm × 60 cm × 100 cm equipped with LEDs with a total power of 60 Watts, LED drivers, and exhaust. The tools used for parameter measurement are the chlorophyll meter SPAD Konica Minolta SPAD-502plus, a chamber photo box equipped with a Samsung A30s 4/64 GB smartphone camera, and a Lenovo IdeaPad 110 laptop equipped with Adobe Photoshop CS6 and Matlab 2017 software, TDS meter, and Lightmeter MS-1300 Voltcraft. The materials needed are Pakcoy (*Brassica rapa* L.) seeds from Benihpedia, fertile soil, manure, Multi Green liquid NPK, Curacron 500 EC syngenta liquid pesticide, polybag, and water.

Experimental Design

This study was conducted in several stages: the preparation of tools and materials, planting and maintenance, observing and measuring variables, and analyzing and processing data. This study used a completely randomized design with one-factor consisting of 7 treatments: P1 (20 Watts red + 20 Watts blue + 20 Watts white), P2 (10 Watts red + 20 Watts blue + 30 Watts white), P3 (10 Watt red + 30 Watt blue + 20 Watt white), P4 (20 Watt red + 10 Watt blue + 30 Watt white), P5 (20 Watt red + 30 Watt blue + 10 Watt white), P6 (30 Watt red + 10 Watt blue + 20 Watt white) and P7 (30 Watt red + 20 Watt blue + 10 Watt white). The data obtained were then analyzed used analysis of variance to determine the effect of treatment on the observed variables. If the result is that the treatment given affects the observed variables, then statistical analysis is continued with Duncan's test using the SPSS Statistics 24 application.

Research Implementations

The stages started from the preparation of tools and materials and the manufacture of the growth chamber. The next stage was sowing the seed. After 14 days, move the seedlings to polybags filled with a mixture of fertile soil and manure in a ratio of 2:1. The treatment was given on the 6th day in a growth chamber equipped with LEDs with a total power of 60 Watts and a light intensity of 2000 ± 20 lux with several proportions of red, blue, and white LED lights for 12 hours from 06.00 WITA to 18.00 WITA. Plant maintenance was carried out from transplanted to before harvest, included watering, nutrition, weeding, and pesticides. Watering does twice a day at a rate of 50 ml/plant water for once watering. Nutrition was carried out on 7 DAP (days after planting) 500 ppm, 14 DAP 700, 21 DAP 900 ppm, 28 DAP 1,200 ppm, 35 DAP 1,300 ppm, and 42 DAP 1,300 ppm. Weeded was carried out once a week, and pesticides were carried out on days 14 DAP and 28 DAP.

Research Variable

The observed variables were chlorophyll content (SPAD value) and canopy area. Variable observations were carried out once a week at the ages of 0, 7, 14, 21, 28, 35, 42 and 49 DAP. Then the data obtained was analyzed by one-way ANOVA followed by Duncan's test using the SPSS Statistics 24 application.

RESULTS

TheEffects of LED Red, Blue, and White Light Colors Proportion on the Chlorophyll Content of Pakcoy

The one-way Anova test showed the proportion of LED light treatment did not significantly affect the chlorophyll content of Pakcoy at the age of 0 to 14 DAP. Meanwhile, at the age of 21 to 49 DAP, the proportion of LED light treatment significantly affected the chlorophyll in Pakcoy. Duncan test results can be seen in Table 1.

Duncan's test results showed that at 49 DAP the average chlorophyll content in the P7 treatment was

significantly different from other treatments. The P7 treatment showed the highest average of chlorophyll content is 35.0 units with a standard deviation of 1.3 (**Fig. 1**), whiled the P4 treatment showed the lowest average of chlorophyll content is 25.4 units with a standard deviation of 2.0 (Fig. 1). The difference in the chlorophyll content of Pakcoy at the age 49 DAP can be seen in **Fig. 1**.

Table 1. The average chlorophyll content of Pakcoy in each treatment

Treatments	Chlorophyll Content (SPAD *value*)							
	0DAP	7 DAP	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP
P1	16.7	22.3	24.4	24.5 a	24.9 a	25.2 a	25.9 a	26.3 a
P2	16.4	23.7	24.3	25.2 a	25.8 a	26.8 a	27.1 a	27.8 a
P3	17.0	23.0	24.0	24.2 a	24.4 a	25.6 a	25.7 a	27.7 a
P4	16.8	22.8	22.9	24.0 a	24.1 a	24.3 a	24.4 a	25.4 a
P5	15.4	25.2	25.6	26.3 a	27.2 a	27.4 a	28.3 a	29.1 a
P6	15.6	21.7	26.0	26.7 a	26.8 a	27.3 a	27.9 a	28.2 a
P7	16.7	24.5	25.4	29.9 b	32.0 b	34.2 b	34.6 b	35.0 b

*) The mean values followed by unequal letters in the same column showed significant differences (P<0.05).

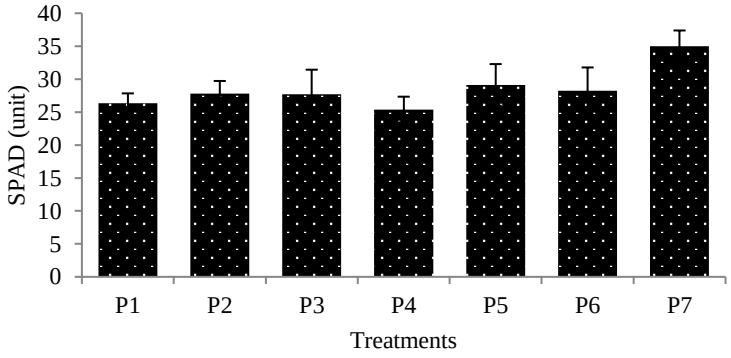

Figure 1. Differences in the chlorophyll content of Pakcoy at the age of 49 DAP

That showed that LED red, blue, and white light colors with a proportion of 3:2:1 has significantly different on the chlorophyll content of Pakcoy. Efficient LED circuits for plant photosynthesis contain approximately 75-90% red light and 10-20% blue light. Therefore, the main color of photosynthetic and photoperiodic lighting is usually red light (Runkle, 2015). Chlorophyll is an important chloroplast component, and chloroplast content has a relatively positive correlation with the rate of photosynthesis. (Li *et al*., 2006). Chlorophyll is synthesized in leaves and is responsible for trapping the sun's rays differently in different species. Chlorophyll synthesis is influenced by many factors such as light, sugars or*k*carbohydrates, water, temperature, genetic factors and nutrition such as N, Mg, Fe, Mn, Cu, Zn, S, O. (Hendriyani and Setiari, 2009). The result of determining the red-light spectrum of the chlorophyll-a and chlorophyll-b contents of each cell of the *Spirulina sp*. given a white spectrum, there is no significant difference (p> 0.05). However, the highest chlorophyll content was obtained when the red spectrum was administered compared to when the blue and white spectra were administered. This indicates that the chlorophyll content can be increased because the red spectrum is more absorbed. (Wicaksono, 2014). Chlorophyll-a and*k*chlorophyll-b more dominantly absorb red light (600-700 nm) and less absorb green light (500-600 nm) (Nurcahyani *et al.,* 2020). While blue light is absorbed by carotenoids. The energy absorbed by chlorophyll-b and carotenoids is transferred to chlorophyll-a for the phase I photosynthesis process (light reaction) which consists of photosystems I and II. Chlorophyll-a is dominant in Photosystem II and chlorophyll-b is dominant in Photosystem I (Nio Song and Banyo, 2011).

The Effects of LED Red, Blue, and White Light Colors Proportion on the Canopy Area of Pakcoy

The one-way Anova test showed the proportion of LED light treatment had no significant effect on the canopy area of the Pakcoy at the age of 0 to 42 DAP, while at the age of 49 DAP the proportion of light treatment had a significant effect on the canopy area of the Pakcoy. Duncan test results can be seen in **Table 2**.

Table 2. Pakcoy's average canopy area in each treatment

Treatments	Canopy Area (cm^2)							
	0DAP	7 DAP	14 DAP	21 DAP	28 DAP	35 DAP	42 DAP	49 DAP
P1	2.1	3.3	8.3	15.1	23.8	35.9	37.5 a	41.5 a
P2	2.1	3.3	8.4	15.0	27.5	37.4	49.7 bc	62.6 cd
P3	2.2	3.5	8.3	15.4	24.8	35.4	42.4 abc	50.7 ab
P4	2.2	3.5	8.2	15.9	27.4	36.0	44.1 abc	56.9 bc
P5	2.0	3.6	7.8	14.5	25.6	36.6	48.4 abc	60.0 bcd
P6	2.1	3.2	8.2	15.5	23.7	34.5	37.9 ab	52.5 bc
P7	1.9	3.6	9.0	15.3	23.4	33.3	51.1 c	70.7 d

*) The mean values followed by unequal letters in the same row showed significant differences (P<0.05).

Duncan's test results showed that at 49 DAP, the average canopy area of the P7 treatment plants was significantly different from the other treatments. The treatment P7 showed an averaged of the widest plant canopy area of 70.7 cm2 with a standard deviation of 4.76 (Fig.2), whiled treatment P1 showed the smallest average plant canopy area of 41.5 cm2 with a standard deviation of 3.41 (Fig.2). Red, blue, and white LED lights with a proportion of 3:2:1 show a positive effect on the canopy area of Pakcoy. The addition of red LED light gave the best effect on the growth of chrysanthemum plants as indicated by the result of the widest canopy area of 478.3 cm^2, while the blue color resulted in a canopy area of 440.03 cm^2 and the white color yielded a height of 395.02 cm^2 (Wiguna *et al.*, 2015). Puspita Nusantara Chrysanthemum, which was given additional light with red LED light had the most extensive leaf area index of 5.5 cm at the age of four weeks compared to green, yellow, blue, white, and TL (Tubular Lamp) light (Syafriyudin and Ledhe, 2015). The ability of leaves to produce photosynthates (the result of photosynthesis) is determined by the productivity per unit leaf area and total leaf area (Haryanti, 2008). Differences in the canopy area of 49 DAP Pakcoy can be seen in **Fig. 2**.

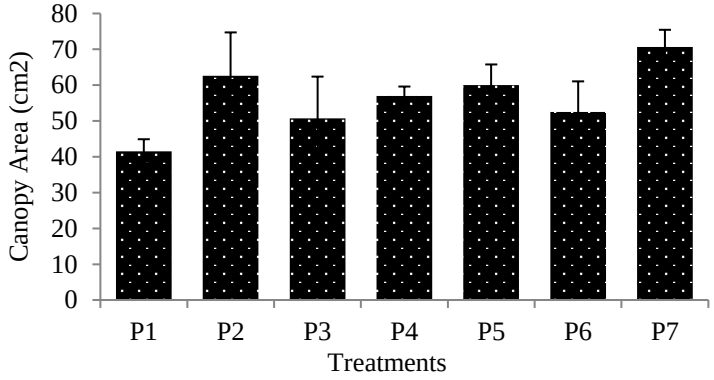

Figure 2. Differences in the canopy area of Pakcoy at the age of 49 DAP

CLONCLUSIONS

The addition of the proportion of red, blue, and white LED light has a positive effect on the chlorophyll content and canopy area. The proportion of red, blue, and white LED light with a ratio of 3:2:1 has a positive effect on the chlorophyll content (35.0 units) and plant canopy area (70.7 cm^2).

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