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Effect of Varying Color LED Lights on *Porang* (*Amorphophallus muelleri*) Bulbil Seed Germination and *Porang* Plant Vegetative Growth Phase

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Abstract. Intensive cultivation is one of the strategies for developing *Porang* commodities to increase production by using LED lights as optimum lighting for *Porang* cultivation. *Porang* bulbil was germinated and planted in a growth chamber with 100% red, 100% blue, 100% white, and 67%:20%:13% red:blue:white lighting. Compared to other LED treatments and sunlight, red:blue:white LED had the best effect on *Porang* plant germination parameters in the first 30 days, with 100% of germination parameters (GP %), 17.2 days of mean germination time (MGT), 6.33%/day of germination rate index (GRI), 5.81% of germination velocity coefficient (CVG), and 138.0 of germination index (GI). For the next 30 days, red:blue:white LED had the best effect on *Porang* plant vegetative growth, with 29.64 cm plant height, 11.43 cm crown diameter, 21.96 cm root length, 17.342 g fresh weight, 1.368 g dry weight, and 57.53 leaf green index. The plant height prediction model is used to predict crop yield, with the coefficient of determination (R^2), root means square deviation (RMSE), mean absolute error (MAE), and average absolute percentage error (MAPE) values up to 0.9854, 0,6894, 1,2623, and 3,9413, respectively, under model validation of the combination of LED.

1 Introduction

Amorphophallus muelleri Blume, also known locally as *Porang*, is a plant species that is being developed as a food source that could be one of the solutions in response to the rising demand for food brought about by a rise in the human population [1-3]. Despite widespread application in food, as a source of 91–95% glucomannan, *Porang* is utilized as a material in the pharmaceutical, biological, and cosmetic industries [2, 4]. Along with many potential applications and purposes of *Porang*, the demand for its industrial raw materials as an export commodity of sliced and dried chips is also increasing significantly [3-5]. However, supply only met the demand for 20% of the available dry chips [6]. The dearth of demand for *Porang* is because it is not cultivated intensively in Indonesia. In addition, the growing demand in export markets will necessitate extensive management of *Porang* cultivation in areas like land preparation for nurseries and planting, plant and land maintenance, and the promotion of *Porang* cultivation as an agro-forestry product and export commodity [1, 6, 7].

Utilizing leaf tubers or bulbils, which are found at the intersections of the leaf stalks, it is possible to achieve intensive *Porang* production through seed propagation [1, 8]. When the petiole spontaneously detaches, indicating complete dormancy, the *Porang* bulbil is harvested as seedlings. Bulbil quality is determined by dormancy and the absence of decaying, peeling, or fungal infections in the seeds [9, 10]. Among the three alternatives, bulbil propagation is the most advantageous in ease, cost, and environmental impact. In every plant's period, the bulbil generated decreases in size as the distance between the leaves and the main branch increases. Production of corms and bulbils varied during the beginning, second, and tertiary crop periods [1, 8].

Using the highest quality seeds is essential to obtain high-yielding, high-quality tubers and seedlings. Numerous factors, such as genotype seeds and their progenitor habitat, landraces, seed pureness, seed shape, seed dimensions, and seed maturity, have impacted seed quality [1, 11]. Because a larger bulbil develops more rapidly than a smaller one, seed size is essential for determining the total reserve amount. A lengthier petiole is indicative of greater viability for heavier seeds. The larger the buds, the taller the plantlets, the drier the branches and roots, the wider the tubers, and the heavier the corms and bulbils during harvest [12, 13]. The success of *Porang* cultivation depends on the availability of seedlings with the proper physiological quality and sufficient quantity [6].

In addition to being genetically determined, seed dormancy, germination, and vegetative growth are also significantly influenced by environmental factors. Light has become one of the most influential environmental factors in determining the extent of dormancy, timing of germination, and growth [11]. The responsiveness of seedlings to light varies significantly between species, with some seeds germinating more readily only in darkness or light, whereas some are unaffected by this variable. Although light is not essential for germination in all species, it mitigates the adverse effects of germination when the incubation temperature exceeds the optimal range [14]. In recent years, light-emitting diodes (LEDs) have been utilized in innovative methods, allowing for plant-targeted development and enhancing quality and productivity concerning environmental control due to LED light's narrow spectral bands and controllable intensity and duration. Success in the LED lighting industry enables using monochromatic wavelengths or their combinations in the red and blue light regions to optimize plant growth and development by providing an efficient light spectrum at the absorption peak of photosynthetic pigments [11, 15-20].

To optimize plant growth, extensive research has been conducted on applying red, blue, and their combination in various tubers [15-20]. In response to light, as an external cue recognized by plants and translated into internal cues, endogenous phytohormones regulate the physiology of seed metabolism [11]. This research was focused on investigating the effect of red, blue, and white LED lights, as well as the combination of red:blue:white, on the germination and vegetative growth phases of the *Porang* plant. This research will contribute to the preparation procedure for planting *Porang* under artificial lighting.

2 Materials and methods

2.1 Sample preparation

Porang seeds (*A. muelleri*) were manually and visually sorted under normal conditions based on their uniform size, approximately 5.00 grams, and absence of infection or damage (Fig. 1). During the third and fourth vegetative phases, *Porang* bulbil samples were collected between June and August from Karangmojo, Kalasan, Yogyakarta, Indonesia.

Fig. 1. The *Porang* bulbil with the normal condition and uniform size.

2.2 Experimental design and growth condition

Porang seeds were germinated and cultivated in a mixture of soil, compost, and husk charcoal as planting medium (approximately 150 g; pH 7.0) in an iron-framed growth chamber with 95% para net coverage. Four different LEDs with varying lux, PPFD, and wavelength, i.e., 100 lux, 44.26 mol·m^{-2}·s^{-1} of PPFD, and 470 nm of wavelength for 100% blue; 600 lux, 20.32 mol·m^{-2}·s^{-1}, and 660 nm of wavelength for 100% red; 1000 lux, 95.92 mol·m^{-2}·s^{-1}, and 550 nm of wavelength for 100% white; 350 lux, 37.33 mol·m^{-2}·s^{-1}, with 660, 470, and 550 nm of wavelengths for the combination of 67%:20%:13% red:blue:white, respectively, were used as artificial light, with the photoperiod was 12 h per day (Fig. 2). For the control treatment, bulbil *Porang* was germinated and cultivated in laboratory conditions of indirect sunlight and an ambient environment. PPFD, lux, and wavelength were measured using a PAR meter and quantum sensor (LICOR LI-250Q PAR comprising LI-250 Light Meter and LI-190R Quantum Sensor), a light meter (Lutron LX-107), and VIS-NIR Ocean Optics spectrometer using a set of fiber-optic probes and a tungsten halogen lamp (HL-2000-HP-FHSA Ocean Optics).

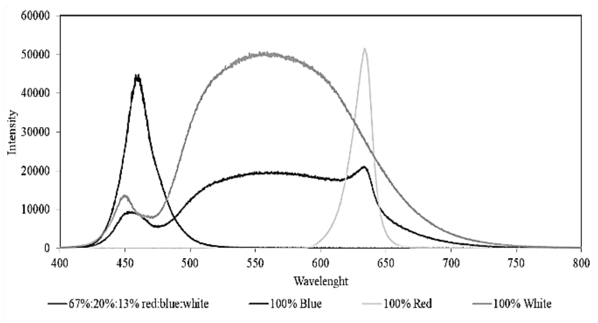

Fig. 2. The light spectrum of red, blue, white, and red:blue:white LED that used in this study.

Porang seedlings were germinated in a 60 cm x 30 cm x 3.5 cm tray with 5 ml of water and no additional nutrients for 30 days. The seeds were then transferred into polybags 15 cm x 15 cm for the next 30 days and then were cultivated under varied LED lights and control with a depth of approximately 5 cm and daily watering of 10 ml without additional nutrition. The environment's temperature is daily recorded in the range of 25-35ºC and relative humidity of 50-80%.

2.3 Determination of germination parameters

After thirty days of seedling growth and development, as indicated by the first apparition of a hypocotyl longer than 0.2 centimeters, the parameters of *Porang* seed germination were measured. Germination Percentage (GP), Mean Germination Time (MGT), Germination Rate Index (GRI), Coefficient of Velocity of Germination (CVG), and Germination Index (GI) were calculated from the observed germination parameters using the equation (1) - (5) [14, 21].

$$\mathrm{GP} = \frac{Number\ of\ gGerminated\ seeds}{Number\ of\ tested\ seed} \times 100\% \quad (1)$$

$$MGT = \sum_{\mathrm{i=1}}^{\mathrm{n}} N_{\mathrm{i}}\mathrm{G_i} \,/\, \sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{G_i} \quad (2)$$

$$\mathrm{GRI} = \frac{\mathrm{GP1}}{\mathrm{d1}} + \frac{\mathrm{GP2}}{\mathrm{d2}} + \ldots \frac{\mathrm{GPx}}{\mathrm{dx}} \quad (3)$$

$$\mathrm{CVG} = \left(\sum_{\mathrm{i=1}}^{\mathrm{k}} \mathrm{f_i} \,/\, \sum_{\mathrm{i=1}}^{\mathrm{k}} \mathrm{f_i x_i}\right)100 \quad (4)$$

$$\mathrm{GI} = (10 \times \mathrm{n1}) + (9 \times \mathrm{n2}) + \ldots + (1 \times \mathrm{n10}) \quad (5)$$

where Ni is the number of days from the day of sowing to the end of the observation; Gi is the number of sprouts on the day of observation; GP1, GP2, and GPx represent the germination percentage on dx days after planting; d1, d2, dx is the day of germination; fi is the number of newly germinated seeds; xi is the number of days from seeding related to fi; k is the final day of germination; n1, n2,... n10 represent the number of seeds that germinated on the first, second, and following day; 10, 9,... 1 represents the weight assigned to the number of seeds that germinate on the first, second, and following day.

2.4 Determination of vegetative growth parameters

Plant height was measured at 7-day intervals, while planting yield was measured 30 days after planting using crown diameter (cm), root length (cm), plant height (cm), fresh weight (gram), and dried weight (gram) of plants. The Computer Vision System (CVS) method determined leaf color by capturing images from both leaf surfaces using a black background and sufficient illumination. Red, green, and blue color values are extracted from the image results using an image processing application.

2.5 Statistical analysis

For each germination and vegetative growth parameter, a one-sample T-test with a significance level of 0.05 was used to compare the effects of the light treatment to the control. The evaluated value represented the statistical difference between the change value and the value at zero. The homogeneity test, Kolmogorov-Smirnov test for normality, and Kurskal Walis's test were used as rank-based nonparametric tests with a significance level of 0.05 to determine the effect of LED light illumination differences. With a significance level between 0.05 and 0.01, Spearman correlation analysis was used to measure the intensity and direction of the linear relationship between the two variables of vegetative growth parameters.

The plant height of 50 samples grown under various color LED lights for 5 weeks was modeled using regression polynomials, beginning on days zero, seven, fourteen, twenty-one, and twenty-eight. Polynomial Regression multiplies independent variables by a polynomial degree in linear Regression. The analysis structures of multiple linear and polynomial regression models are identical. Each rank or order in a polynomial model modifies the initial variable, transforming a free variable into a non-free variable [22].

This investigation used a calibration set of seven samples to build the model, while a validation set of three samples was used to evaluate the model. The predictive error values of the calibration and prediction sets were examined to evaluate the accuracy of the model's performance. The model was evaluated using root mean square error (RMSE), mean absolute error (MAE), mean absolute percentage error (MAPE), and coefficient of determination (R^2). The polynomial equation and model evaluation are listed in equations (6) - (10); n is the number of samples, ý is the predicted value of the plant height at the i-point, and y represents the actual plant height at the i-point [22].

$$y = \beta_0 \sum_{j=i}^{d} \beta_j x_i^j + \varepsilon_{i,j} = 1,2,3,n \quad (6)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \acute{y}_i)^2} \quad (7)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |\, y_i - \acute{y}_i \,| \quad (8)$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n} \frac{|\, y_i - \acute{y}_i \,|}{\acute{y}_i} \quad (9)$$

$$R^2 = \frac{\sum_{i=1}^{n}(y_i - \acute{y}_i)(\acute{y}_i - \acute{y}_i)^2}{\sum_{i=1}^{n}(y_i - \acute{y}_i)^2 \sum_{i=1}^{n}(\acute{y}_i - \acute{y}_i)^2} \quad (10)$$

3 Results and discussion

3.1 Relationship between the Growth Chamber's Light Intensity, Temperature, and Humidity

Fig. 3 shows the effect of various lighting colors on the microclimate condition in the growth chamber. In this investigation, light intensity measurements showed that each LED color had a different intensity. White LEDs emit the lightest with an average irradiance of 12000 lux, followed by combination LEDs at 1300 lux, red LEDs at 700 lux, and open space controls at 300 lux, while blue LEDs gave the lowest light intensity at 240 lux. LED lights maintained a more consistent temperature than sunlight. White LEDs had the highest temperature (31.6ºC), mixture LEDs had the lowest (30.2ºC), and the control treatment had a temperature of 30.6ºC. With LED lighting, the growth chamber humidity increased, while the control treatment humidity fluctuated during each observation. White LED treatment had the lowest humidity at 61.8%. This LED treatment makes the growing chamber dry and hotter than others. Red and blue LED lights produce 66% and 63.6% humidity. The 71% combination LED treatment is closest to the control treatment's 79% humidity. According to other reports, this study's microclimate temperature and humidity are appropriate for the optimal condition; porang plants thrive at 25-35ºC and 50-80% RH [22].

3.2 Germination parameters of Porang bulbils under varying LED lights

Table 1 shows the effect of various lighting colors on the evaluated seed germination parameters, with the best GP, MGT, GRI, CVG, and GI values obtained by applying the LED combination of red:blue:white, with respective values of 100%; 17.2 days; 6.33% per day; 5.81%; and 138.00.

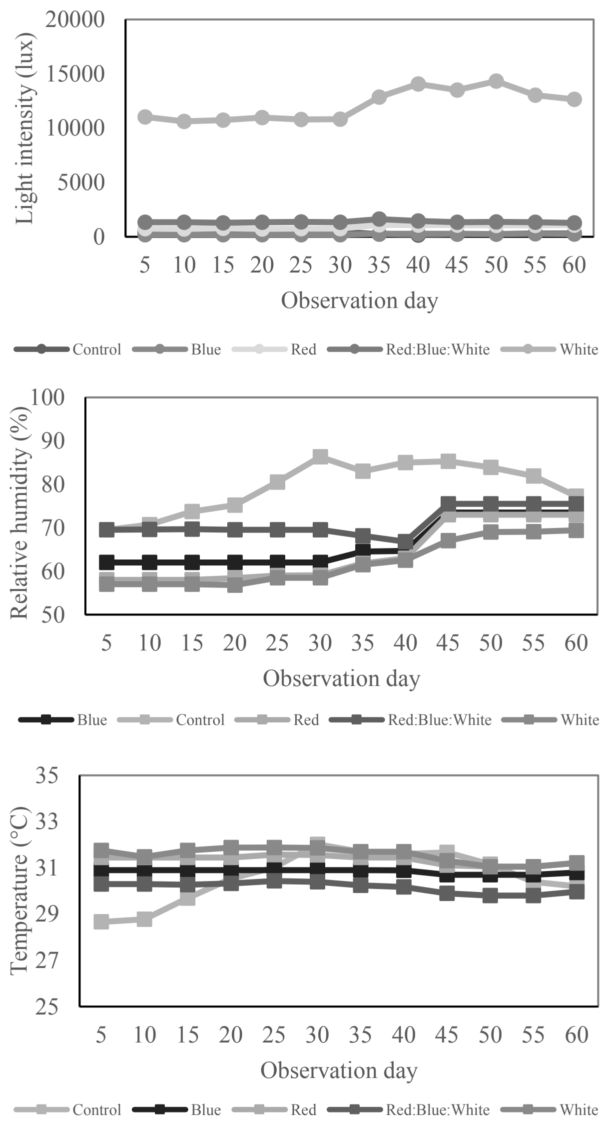

Fig. 3. Effect of differences in light treatment on microclimate conditions observed during the growth of bulbil porang.

GP (%) shows the percentage of final germination achieved by *Porang* bulbils under various irradiation color LED lights. Within 30 days, cultivation under LED combination of red: blue: white produced the best germination rate (100%), followed by control treatment (90%), blue LED (80%), and the lowest was red LED and LED white (70%). The development of the number of seeds that germinated as germination capacity (%) for each treatment is shown in Fig. 4. The seeds in each treatment showed an increase in germination. Seeds can respond differently to various types of light, not only as a source of energy to produce organic compounds but also as a supply of information to plants that regulate their growth and development in response to environmental changes [11].

The MGT (days) is calculated over 30 days, revealing that the average yield of seed germ indicating more rapidly occurs between days 15 and 20 (Fig. 4). The shorter the MGT (days), the more rapidly a seed population germinates [14, 21]. It is known that red:blue:white LEDs generated the maximum MGT of 17.2 days for *Porang* bulbil, whereas red LEDs resulted in the lowest MGT of 20.7 days.

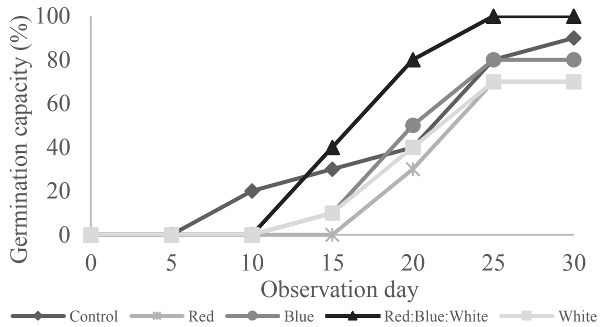

Fig. 4. The germination capacity of Porang bulbil increases by 30 days.

GRI (percent per day) represents the daily germination percentage of *Porang* bulbil seeds; the more significant the GRI value, the higher and more rapid the germination process [21]. *Porang* bulbil germinated under red: blue: white LED light had the highest GRI value of 6.33%/day, followed by the control treatment with 5.79%/day and the red LED treatment with 3.45%/day. Like GRI, GI focuses on the germination rate and rate of germination. In GI calculations, however, the highest value is assigned to seeds germinating on the first day, and the lowest is germinating on the following day [21]. In germinated *Porang* bulbils, the red:blue:white LED combination treatment provided the highest GI value of 138.00, just above the control treatment of 113.00. In contrast, the red LED treatment provided the lowest GI value of 72.00.

Table 1. Effect of differences in light treatment on bulbil *Porang* germination parameters.

Treatment	GP (%)	MGT (days)	GRI (%/days)	CVG (%)	GI
Control	90	18.4	5.79	5.42	113.00
Red	70	20.7	3.45	4.83	72.00
Blue	80	19.0	4.43	5.26	96.00
Red:Blue:White	**100**	**17.2**	**6.33**	**5.81**	**138.00**
White	70	19.0	3.92	5.26	84.00
Kruskal Walis's test	ns	ns	ns	ns	ns
One sample T-test	*	*	*	*	*

Note: * are significantly different at $\alpha = 0.05$.

CVG signifies the rate of germination, whose value rises as the proportion of seeds that germinate and the time needed for germination decrease [21]. The obtained CVG (%) indicates a slow pace germination process, which may be due to the length of time bulbil *Porang* seeds require to germinate. *Porang* bulbil germinated under a red:blue:white LED combination had the maximum CVG (%) at 5.81%, while the red LED treatment had the lowest CVG (%) at 4.8%.

Red and blue LED light has been regarded as the essential spectrum for plant growth, as it is not only the primary source of light for photosynthesis but also controls numerous morphogenetic responses in plants via photoreceptors [11].

3.3 Vegetative growth parameters of *Porang* bulbils under varying LED lights

Porang plant growth and development respond differently to each LED exposure. Concerning plant height, *Porang* grown under red light grew taller than *Porang* grown under blue light (Table 2), but both grew shorter than *Porang* grown under a combination of red and blue light. The monochromatic red light induces a shade avoidance syndrome, which results in excessive stem elongation and a less refined plant body. In contrast, blue light inhibits plant organ elongation [23]. In addition, blue light has a lower capacity for energy absorption than red light [24].

Table 2. Effect of differences in light treatment on vegetative growth parameters of *Porang* plant.

Treatment	Plant height (cm)	Crown diameter (cm)	Root length (cm)	Fresh weight (g)	Dry weight (g)	Leaves color		
						R	G	B
Control	26.20 ± 24.86	8.20 ± 9.41	14.22 ± 8.57	15.615 ± 8.948	1.347 ± 0.694	29.61	38.50	11.91
Red	22.02 ± 17.40	4.80 ± 6.45	19.64 ± 9.74	15.237 ± 7.939	1.272 ± 0.627	39.12	43.27	14.81
Blue	18.59 ± 17.06	7.45 ± 9.36	13.77 ± 12.41	14.153 ± 7.035	1.216 ± 0.360	32.31	40.84	8.79
Red:Blue:White	**29.64 ± 16.55**	**11.43 ± 9.26**	**21.96 ± 6.02**	**17.342 ± 8.891**	**1.368 ± 0.331**	**47.40**	**57.53**	13.56
White	13.30 ± 9.92	5.35 ± 6.64	21.47 ± 9.27	12.864 ± 5.633	1.259 ± 0.438	30.15	36.06	8.18
Kruskal Walis's test	ns	ns	ns	ns	ns	ns	ns	ns
One sample T-test	*	*	*	*	*	*	*	*

Note: * are significantly different at α = 0.05.

In this study, *Porang* plants grown under a red:blue:white LED combination had the highest values for plant height, crown diameter, root length, plant weight, and color parameters (Table 2). The red, blue, and white LED combination has a ratio of 67%, 20%, and 13%, respectively, which is close to the specifications for a suitable LED color combination for plant growth. When applied at the right intensity, red light combines with blue light to govern plant responses, and an optimal R:B ratio enhances photosynthetic capability, growth, and yield [25].

The use of various wavelengths on different LED light colors caused a difference in the height of the *Porang* plant, with the highest value being 29.64 cm for the red:blue:white LED combination and 13.30 cm for the white LED, as a result of the auxin hormone, plant height increases in low light intensities. Auxin, a plant hormone that affects cell elongation, is susceptible to injury or degradation when exposed to intense light. However, some reported that white light is conducive to developing various horticultural products and advantageous for photosynthesis because more light can penetrate the canopy to lower leaves than red and blue lights [15].

In addition to plant height, the use of different wavelengths in various LED light colors affects the diameter of the *Porang* crown, with the highest diameter obtained from the LED combination of red:blue:white at 11.43 cm and the lowest value obtained from white LED at 5.35 cm. The leaves, branches, and twigs contribute to the crown diameter. Since crown morphology can affect plant light absorption, crown diameter is an essential parameter in *Porang* cultivation. In the vegetative growth phase of plants, root growth is crucial because long roots can maximize the absorption of water and minerals from the medium, resulting in increased plant canopy growth [26, 27]. The use of spectra of various LED light colors affects the root length of *Porang* plants, with the LED combination of red:blue:white producing the longest roots at 21.96 cm and the blue LED producing the shortest roots at 13.77 cm.

The red:blue:white LED spectrum produced the highest fresh weight yield of *Porang* plants (17,342 g) compared to the control treatment (15,615 g). The fresh weight under the red LED light treatment was remarkably comparable to the control treatment (15,237 g), followed by the blue LED treatment (14,153 g) and the white LED treatment (12,864 g). The LED combination of red:blue:white can increase the overall yield of *Porang* plants by 10% over the control condition and by 34.8% over the white LED condition. Red and blue LEDs can increase plants' fresh and dried weight [28-30]. In comparison, the lowest weight of plants grown under white LED lighting is due to slow plant growth, which can reduce total plant weight [31]. The use of different wavelengths on different LED light colors caused differences in the weight of the *Porang* plant, with the highest fresh and dry weight obtained from the LED combination of red:blue:white by 17,342 g and 1.368 g, respectively, the lowest fresh weight obtained from white LEDs by 12.864 g and the lowest dry weight obtained from blue LEDs by 1.216 g.

The plants absorb red light more efficiently than blue light [24]. Applying LEDs between 380 and 660 nm induced multiple phytochromes in seed potato tubers to produce green color intensity in response to irradiance [20]. However, by stimulating chlorophyll production in plants, blue light affects plant compaction and leaf discoloration [32]. In this study, plants exposed to monochromatic red light performed better than those exposed to blue LED light. Compared to the LED combination of red, blue, and white treatment, the monochrome blue or red-light treatment resulted in subtler leaf colors and a lighter shade of green. The wavelengths of distinct LED light colors affect the leaf color of the *Porang* plant; the LED combination of red:blue:white produced the best results with a green (G) color index value of 57.33, a red (R) color index value of 47.40, and a blue color index value of 13.56. Other reports mentioned that the LED combination of red:blue: and white produced the highest accumulated photosynthetic pigment and induced green color and was claimed as appropriate light for potato pre-basic seed tuber cultivated under plant factory conditions [19].

The Spearman correlation between the vegetative growth characteristics of the *Porang* plant, such as plant height, root length, crown diameter, fresh and dry weight, and leaf color parameters, was measured and shown in Table 3. Positive and highly significant correlations exist between plant height and crown diameter (rho = 0.726), fresh weight (rho = 0.887), and leaf color parameters of R, G, and B index (rho = 0.720, 0.798, and 0.700, respectively). The crown diameter was positively and highly correlated with fresh weight (rho 0.816) and G index (rho 0.814), yielding a high correlation coefficient.

3.4 The vegetative growth model of the *Porang* plant based on plant height

Plant height in the vegetative growth phase of *Porang* plants cultivated under LED lighting with varying colors is shown in Fig. 5. Based on the graph, the final height of *Porang* plants exposed to the LED combination of red:blue:white light was the greatest (27.96 cm) when compared to other LED treatments. Based on the average weekly height during the five-week cultivation of *Porang* plants, a model of the vegetative growth of *Porang* plants under blue LED, red LED, combination LED, and white LED treatments was developed.

Table 3. Correlation between *Porang* plant vegetative growth parameters.

Vegetative growth parameter		Plant height	Root length	Crown diameter	Fresh weight	Dry weight	R	G	B
Plant height	P	1.000	.407**	**.726****	**.887****	-.366**	**.720****	**.798****	**.700****
	Sig.	.	.003	.000	.000	.009	.000	.000	.000
Root length	P		1.000	.515**	.454**	-.373**	.435**	.450**	.485**
	Sig.		.	.000	.001	.008	.002	.001	.000
Crown diameter	P			1.000	**.816****	-.496**	**.709****	**.814****	.620**
	Sig.			.	.000	.000	.000	.000	.000
Fresh weight	P				1.000	-.407**	**.788****	**.855****	**.710****
	Sig.				.	.003	.000	.000	.000
Dry weight	P					1.000	-.514**	-.501**	-.617**
	Sig.						.000	.000	.000
R	P						1.000	**.933****	**.820****
	Sig.							.000	.000
G	P							1.000	**.734****
	Sig.								.000
B	P								1.000
	Sig.								.

Note: * are significantly different at α = 0.05, and ** are significantly different at α = 0.01.

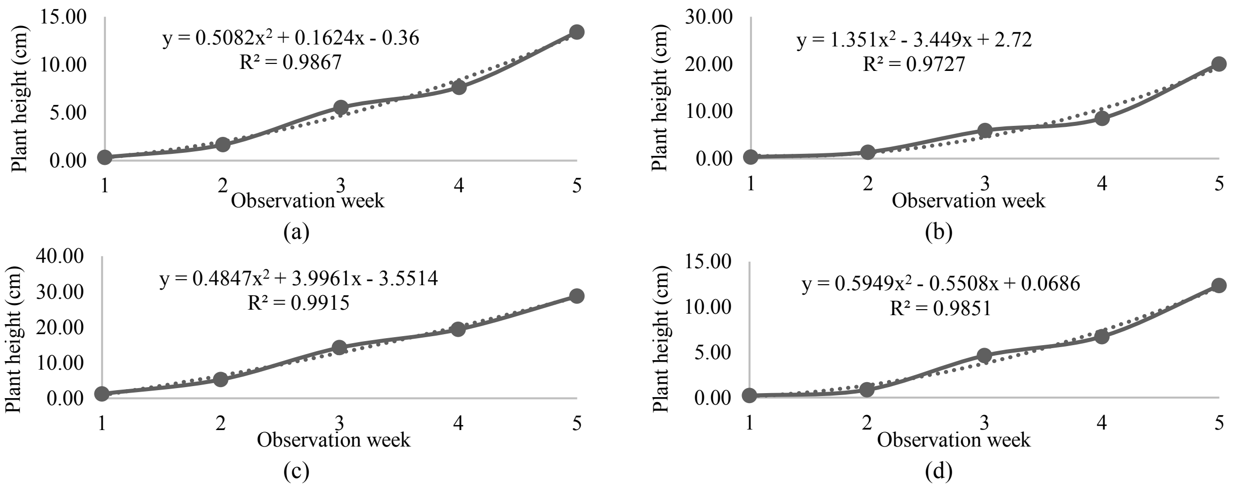

Fig. 5. The modeling result of the observation of vegetative growth of *Porang* plant height on red LED (a), blue LED (b), combination LED (c), and white LED (d) using the calibration set.

The various treatments of 100% red LEDs, 100% blue LEDs, a combination of 67%:20%:13% red:blue:white LEDs, and 100% white LEDs have coefficients of determination of 0.9760, 0.9867, 0.9727, 0.9915; 0.9851, respectively. These results indicate a strong correlation between the height development of *Porang* plants and planting time. In addition, the five models can be used to predict the height of *Porang* plants under varying LED light color variations.

Based on the results of the evaluation of the plant height prediction model on the calibration and validation sample set, the most appropriate performance model was obtained from the LED combination of red:blue:white, with an R^2 of 0.9915; RMSE of 0.4052; MAE of 0.7699; and the MAPE of 2.4472, in the calibration set, and with an R^2 of 0.9854; RMSE of 0.6894; MAE of 1.2623; and the MAPE of 3.9413, in the validation set (Table 4). In general, the four models have a deficient error between the predicted value and the actual value; based on the reliable performance model, the four models can be used as an appropriate measure for estimating the growth of *Porang* plant height during the vegetative phase of growth under varying color LED lighting as artificial lighting.

Table 4. Performance model comparisons of *Porang* plant height cultivated under varying LED lighting.

Treatment	R^2	RMSE	MAE	MAPE
Calibration set				
Blue	0.9867	0.2403	0.4414	2.2683
Red	0.9727	0.5222	0.9337	6.3973
Red:Blue:White	**0.9915**	**0.4052**	**0.7699**	**2.4472**
White	0.9851	0.2408	0.4578	5.3712
Validation set				
Blue	0.9729	2.9442	4.1959	6.3792
Red	0.9845	2.1986	1.7081	5.9990
Red:Blue:White	**0.9854**	**0.6894**	**1.2623**	**3.9413**
White	0.9606	0.5354	0.7150	5.5202

4 Conclusions

The use of varying color light, 100% red, 100% blue, 100% white, and the combination of 67%:20%:13% red:blue:white, affects *Porang* bulbil germination and *Porang* plant vegetative growth, with all parameter values better than the control treatment. Percent germination (GP) by LED combination of 67%:20%:13% red:blue:white achieved 100% as the highest value, with the shortest average germination time (MGT) of 17.2 days, and other parameters, such as germination rate index (GRI), germination rate coefficient (CVG), and germination index (GI), 6.33%/day; 5.81%; and 138.00, respectively. In addition, the application of LED combination can provide more optimal light requirements for the vegetative growth of *Porang* plants, with a higher plant height of 29.64 cm, crown diameter of 11.43 cm; root length of 21.96 cm, fresh weight of 17.342, and dry weight of 1.368, with 57.53 leaf green index. The polynomial model's performance analysis was precise and reliable, with a high R^2 value for varying color LED lights, with the obtained RMSE, MAE, and MAPE values also relatively modest. Based on plant height, the *Porang* vegetative growth model allows for predicting the height of *Porang* plants grown under artificial lighting.

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