

EFFECT OF BLUE LED POWER AND SELENIUM BIOFORTIFICATION ON THE PRODUCTION AND BIOACTIVE CONTENT OF RED CABBAGE MICROGREENS PLANTS

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ARTICLE HISTORY:

Received: 19 March 2025
Peer Review: 15 April 2025
Accepted: 22 July 2026

KEYWORDS:

Blue LED power, bioactive, production, red cabbage microgreens, selenium biofortification

ABSTRACT

Red cabbage can be consumed in its early growth stage or as microgreens due to its higher nutritional content than mature vegetables, thus attracting attention as a functional food. The use of LEDs (light-emitting diodes) is an alternative in indoor farming systems. Light intensity can be achieved through a power-based approach. Optimal blue light is able to efficiently form chlorophyll, assimilate carbon, and grow biomass. Microgreen nutrition can be improved through a selenium biofortification process. The study aims to increase the production and bioactive content of red cabbage microgreens with different blue LED power and selenium concentrations. The study was conducted from October to November 2024 at the Physiology and Plant Breeding Laboratory, Faculty of Animal Husbandry and Agriculture, and the Chemical Engineering Laboratory, Faculty of Engineering, Diponegoro University. The study used a split plot design with 3 main plot levels and 4 subplot levels based on a completely randomized design with 3 replications. The main plot was blue LED power of 12, 15, and 18 watts, while the subplots of selenium concentration treatments consisted of 0, 20, 40, and 60 μM , resulting in 36 experimental units. The results showed that the 18-watt blue LED power treatment was effective for increasing the fresh weight of the shoot and water content. Selenium biofortification treatment with a concentration of 20 μM was effective in increasing carotenoid levels. The 18-watt blue LED power combined with a selenium concentration of 40 μM can increase the highest total anthocyanin content. These findings demonstrate the importance of light management and fortification to increase the production and quality of microgreens.

1. INTRODUCTION

As a member of the Brassicaceae family, red cabbage has many health benefits, including the potential to prevent cancer due to its high antioxidant content. Because red cabbage has a higher nutritional content than mature veggies, it can be eaten in early growth or microgreens, drawing interest as a functional food. Compared to mature red cabbage, red cabbage microgreens have twice as much vitamin C, 2,5 times as much antioxidant activity, and twice as many total glucosinolates (Drozdowska *et al.*, 2020).

One of the creative ways to combat the issue of land conversion through indoor gardening is with microgreens. One option to the indoor farming technique that can increase the quantity and quality of plants is the use of technologies like Light-emitting Diode (LED). Blue LED light offers the versatility to enhance the quality of microgreens by manipulating plant physiological processes. The 400–500 nm wavelength of blue LED light can encourage microgreens to produce more antioxidant chemicals. By subjecting plants to extreme blue light stress, large doses of blue light can raise the bioactive content of plants. Compared to yellow and red LEDs, kale microgreens under blue LED can have the maximum water content (95%) and carotenoid concentration (5,59 $\mu\text{mol/L}$) (Mardiyani *et al.*, 2023). High and low light intensity can be set through a power-based approach. Carbon assimilation, biomass growth, and chlorophyll production may all be accomplished efficiently with the right amount of blue light. In comparison to red and control, blue LED light is the most effective at growing the stem, number of leaves, and height of pakcoy microgreens. The ideal intensity is 15 watts, as opposed to 9 and 3 watts (Putri *et al.*, 2021). In comparison to 8 and 10 watts of lamp power, the sunflower microgreens with the maximum chlorophyll concentration at 12 watts had 29.18 units (Sendari *et al.*, 2023). Because blue LED intensity promotes the buildup of secondary metabolites, it contributes to the increase of antioxidant molecules. Kohlrabi microgreens anthocyanins increased with blue light intensity (55,75 vs 9,81 W/m^2), with a mean of 14,94 mg/L/g fresh weight, which was greater than 6,63 mg/L/g fresh weight (Cowden *et al.*, 2024).

Improving the quality of microgreens as functional food can be done through the process of biofortification of selenium compounds. As an essential element, selenium is effective in increasing plant defense by synthesizing secondary metabolites such as antioxidant. Selenium enrichment of 100 $\mu\text{mol/L}$ Na_2SeO_3 in broccoli sprouts increased anthocyanin content by 9,13 – 9,88 $\mu\text{g/g}$ fresh weight compared to no Se (7,29 $\mu\text{g/g}$ fresh weight) (He *et al.*, 2020). The production of biomass and secondary metabolites can be optimized through the biofortification process with selenium micronutrients. A concentration of 40 μM sodium selenate (Na_2SeO_4) was effective in increasing 24 $\mu\text{g/g}$ Se of kale microgreens higher than 0, 10, and 20 μM (Tavan *et al.*, 2024). Sodium selenate concentration of 50 μM was optimal in increasing the phenol content of broccoli sprouts 120,09 mg/100 g compared to the control (Bachiega *et al.*, 2016).

2. MATERIALS AND METHOD

The research was carried out in October – November 2024 at the Laboratory of Plant Physiology and Breeding, Faculty of Animal and Agricultural Sciences, and the Chemical Engineering Laboratory, Faculty of Engineering, Diponegoro University. The materials and tools used in the research are red cabbage seeds (PT. Known You Seed Indonesia), aquades, acetone 80%, ethanol 70%, methanol, selenium dioxide (SeO_2), cocopeat, 1 watt blue HPL light-emitting diode (LED) lamp + star PCB diameter 19 mm with working voltage 3,0 – 3,3 VOLT and working current 200 – 300 mA, as well as wavelength 460 – 465 nm, HPL LED driver large power 8 – 12 watts and 12 – 18 watts with a wide input voltage range of 85 – 265 VOLT AC and constant current up to 300 mA, digital themohyrometer, screwdriver, hand sprayer, camera, analytical scale, 500 mL thinwall size (17,5 cm $\times$ 9,5 cm $\times$ 4 cm) and

200 mL, thinwall size (10,8 cm × 6 cm × 4 cm), whatman paper, ruler, mortar-pistil, beaker, measuring cup, measuring flask, magnetic stirrer, test tube, pipette, cuvette, UV-Vis spectrophotometer (Shimadzu Corp. UVmini-1240 type), power cord, automatic contact timer set, wood plywood, solder, tin, silicone glue, black insulation, double tape foam, cardboard, brown envelopes, ovens, and laptop.

2.1 Experimental Design

This experiment was carried out using a split plot design with 3 main plot levels and 4 subplot levels based on a Completely Randomized Design (CRD) with 3 replicates. The main plot was the blue LED power (B), namely 12 watts (B1), 15 watts (B2), and 18 watts (B3), while the subplot was the selenium concentration (S) consisting of 0 µM (S1), 20 µM (S2), 40 µM (S3), and 60 µM (S4), with the total of 36 experimental units.

2.2 Indoor Farming Installator

This research procedure began with the preparation of growthboxes according to the layout of 9 units arranged with 3 × 3 shelves with a size of 60 × 60 × 60 cm. Twelve, fifteen, and eighteen LEDs (High Power LEDs) with an eye that had a power of one watt and a blue spectrum wavelength of 460 to 465 nm were then installed in each growth-box, 36 cm from the planting medium's surface. The LED lights are turned on from 5 day after planting (DAP) to 9 DAP for 12 hours (08.00-20.00 WIB) using an automatic timer.

2.3 Microgreens Establishment and Treatment

A 1 L selenium stock solution (1 mM) was prepared and diluted to treatment concentrations of 0, 20, 40, and 60 µM. A total of 2,9 g of red cabbage seeds was allocated to each of 36 units. From each unit, 100 seeds were separated for germination analysis using different containers. Cocopeat growing media was moistened and filled into two container sizes (500 mL and 200 mL thinwalls) up to $\frac{3}{4}$ volume. Each growth box held 8 containers: 4 with 2,9 g seeds and 4 with 100 seeds for germination tests. Seeds were broadcasted onto the media and kept in darkness for 5 days to stimulate germination. Maintenance involved foliar spraying of selenium solution (30 mL per treatment unit, 10 mL for germination units) on days 6 and 8 after planting. Watering was done as needed to maintain media moisture. Environmental parameters (temperature, humidity, and PPFD) were monitored thrice daily. Harvesting occurred on day 9 after planting by cutting at the base of the stem near the media surface.

2.4 Observed Parameters and Statistical Analysis

The parameters observed were microgreen height, seed germination percentage, fresh and dry weight, biomass water content, carotenoid and chlorophyll content, and total anthocyanins. The amount of chlorophyll and carotenoid was measured by using the method of Pangestika *et al.* (2022), with few adjustment. Chlorophyll and carotenoid content were analyzed after harvest using the UV-Vis spectrophotometer. As much as 0,25 g of sample was crushed, and then dissolved in 25 ml of acetone (80%). Whatman paper is used to filter the extract before it is placed in a cuvette to measure its absorption. The absorbance was detected at the wavelengths of 480, 663, and 645 nm. The formula for calculating chlorophyll content is adopted from Harborne (1987) and carotenoid content based on Hendry and Grime (1993) as follows:

$$\text{Chlorophyll A (mg/g)} = [(12,7 \times A_{663}) - (2,69 \times A_{645})] \quad (1)$$

$$\text{Chlorophyll B (mg/g)} = [(22,9 \times A_{645}) - (4,68 \times A_{663})] \quad (2)$$

$$\text{Total Chlorophyll (mg/g)} = 20,2 \times A_{645} \text{ nm} + 8,02 \times A_{663} \text{ nm} \quad (3)$$

$$\text{Carotenoid Content (mg/g)} = \frac{[A_{480} + (0,114 \times A_{663}) - (0,638 \times A_{645})] \times V \times 10^3}{112,5 \times W} \quad (4)$$

Notes: A480 = absorbance at wavelength 480 nm, A645 = absorbance at wavelength 645 nm, A663 = absorbance at wavelength 663 nm, V = volume of extract (mL), and W = wet weight of sample (g).

Total anthocyanins were measured by using the pH difference method according to Giusti and Wrolstad (2001) with few modifications. Samples of each treatment, weighed 1 g each, were crushed with mortar and extracted with rotatory evaporator. Two buffer solution samples were prepared, namely KCl buffer at pH 1 and Na-Acetate buffer at pH 4,5. The sample was then put into each buffer to a volume of 10 mL (dilution factor = 10), and left for 1 hour, then filtered with whatman paper before being placed in a cuvette. The absorbance of each sample was measured with UV-Vis spectrophotometer at the wavelengths of 536 nm and 700 nm. The absorbance value is determined by the following equation:

$$\text{Equation A} = [(A_{536} - A_{700}) \text{ pH 1} - (A_{536} - A_{700}) \text{ pH 4,5}] \quad (5)$$

Total anthocyanins can be calculated through the formula of Lee *et al.* (2005) as follows:

$$\text{Total anthocyanins (mg/L)} = \frac{A \times MW \times DF \times 1000}{\epsilon \times I} \quad (6)$$

Note: A = absorbance value, MW = molecular weight (449,2 g/mol), DF = dilution factor, ϵ = molar absorptivity cyanidin-3-glucoside (26900), and I = cuvette thickness (1 cm).

Collected data were analyzed using the analysis of variance (ANOVA) at 5% significance. When there was a significant effect, the means of the data were further analyzed with the Duncan's Multiple Range Test (DMRT) test at the significance level of 5%, as well as the Orthogonal Polynomial test to see the trend and optimal response value.

3. RESULT AND DISCUSSION

3.1. Microgreens Height

The result of analysis of variance showed that blue LED power treatment had no significant effect on the height of red cabbage microgreens, neither did the selenium biofortification treatment nor their interaction effect (Table 1). Although the blue LED power did not have a significant effect on the height of red cabbage microgreens, it seems that the 12 watts blue LEDs (equivalent to 69,0 $\mu\text{mol/m}^2/\text{s}$ PPFD) produced slightly higher average yields. This is in accordance with the report by Johnson *et al.* (2020) that arugula seeds germinated at a low intensity of blue-light could encourage stem elongation in response to shade avoidance. The results of other studies show that the provision of lower intensity produces taller plants. This further exemplified by Hernandez-Adasme *et al.* (2023) when beet microgreens were grown at 220 $\mu\text{mol/m}^2/\text{s}$ produced shorter hypocotyls than those grown at 160 $\mu\text{mol/m}^2/\text{s}$, because blue light generally inhibits stem elongation in plants, resulting in shorter, more compact plants with thicker leaves.

Selenium biofortification treatment with different concentrations did not significantly affect the height of red cabbage microgreens (Table 1). This is thought to be because selenium treatment focuses more on increasing biochemical compounds than plant growth of microgreens such as height and fresh weight. This is reinforced by the research of Tavan *et al.* (2024) giving selenium through foliar application on kale microgreens of various concentrations (0, 10, 20, and 40 μM) did not give significant results on stem length with an average of 30,8 – 33,9 mm. Selenium biofortification in microgreens is thought to be able to interfere with nutrients in the growing media. This is in line with the opinion of Islam *et al.* (2020) the addition of selenium to wheat microgreens did not affect plant

height and weight, due to competition between selenium and other essential ions transported through the growing media.

3.2. Percentage of Seed Germination

The result of analysis of variance showed that the blue LED power treatment had no effect on the percentage of seed germination of red cabbage microgreens, neither did the selenium biofortification treatment nor their interaction effect (Table 2). Table 2 showed that the intensity of blue LED power at 12, 15, and 18 watts (equivalent to light intensity of 69,0 – 119,3 $\mu\text{mol}/\text{m}^2/\text{s}$ PPFD) did not significantly affect the percentage of seed germination of red cabbage microgreens. This finding agreed with Kong *et al.* (2019) that seed germination among microgreens species of arugula, cabbage, kale, and mustard was not affected by blue light intensity at 50,7/100,5 $\mu\text{mol}/\text{m}^2/\text{s}$ PPFD (LLI/HLI). The results showed the percentage of normal seed germination of red cabbage microgreens at 9 DAP was 66,33 – 47,67% below 80%. This is in accordance with the research of Sendari *et al.* (2023) which states that LED light intensity of 8, 10, and 12 watts does not affect the percentage of normal germination at the age of 7 day after sowing of sunflower microgreens which is 79,33 – 85,33%. Seed germination carried out in dark conditions is determined by differences in species. This is reinforced by Vatistas *et al.* (2024) the germination process carried out in 24 hours resulted in 100% germination in lettuce and spinach, 30% cabbage, and 45% arugula. This is thought to be because the provision of LED light is not needed at 0 - 4 DAP, but environmental factors such as temperature and humidity that affect the germination process.

Selenium biofortification treatment with different concentrations did not significantly affect the germination of red cabbage microgreens (Table 2). It is suspected that the selenium biofortification method in the study was carried out by foliar spray method at the age of 6 and 8 DAP and was not done at the beginning of germination. This opinion is supported by the research of Tavan *et al.* (2024) selenium biofortification in kale microgreens given by foliar treatment concentrations of 0 (control), 10, 20, and 40 μM with a dose of 15 mL applied 3 times at 5, 7, and 10 DAP.

Table 1. Height of Red Cabbage Microgreens in Response to Blue LED Power Treatment and Selenium Biofortification at 9 Day After Planting (DAP).

Blue LED Power (watt)	Selenium Concentration (μM)				Average
	0	20	40	60	
	----- (cm) -----				
12	5,85	5,74	5,54	5,89	5,75
15	5,36	5,60	5,99	5,19	5,53
18	5,22	5,35	5,68	6,36	5,65
Average	5,48	5,56	5,74	5,81	

Table 2. Percentage of Seed Germination of Red Cabbage Microgreens under Blue LED Power Treatment and Selenium Biofortification at 9 DAP.

Blue LED Power (watt)	Selenium Concentration (μM)				Average
	0	20	40	60	
	----- (%) -----				
12	47,67	57,67	56,67	54,00	54,00
15	50,00	56,67	54,33	60,33	55,33
18	66,33	59,67	49,33	54,33	57,42
Average	54,67	58,00	53,44	56,22	

Selenium concentration at some levels is thought to give negative results or reducing germination percentage. This is in accordance with Naseem *et al.* (2021) that the administration of selenium to plants can inhibit growth, which is associated with decreased pigment activity in plants. The germination percentage is also affected by the level of plant spacing density, because microgreens are planted with high density. This is reinforced by Ortiz *et al.* (2024) microgreens seeds grown with a seed density of ± 66.000 seeds/m² and 26.000 seeds/m² of broccoli and radish can affect the percentage of germination by 90%.

3.3. Fresh Weight of Microgreens

Red cabbage microgreens fresh weight was affected by blue LED power treatment (Table 3). Selenium biofortification treatment did not affect the fresh weight of red cabbage microgreens, and there was no interaction effects between both treatments. Table 3 showed that blue LED significantly influenced the fresh weight of red cabbage microgreens. This indicates that the difference in blue LED power of 12, 15, and 18 watts (equivalent to light intensity of 69,0 – 119,3 $\mu\text{mol}/\text{m}^2/\text{s}$ PPFD) is able to increase the fresh weight of red cabbage microgreens. This is reinforced by the research of Liu *et al.* (2022) that LED intensity below 50 $\mu\text{mol}/\text{m}^2/\text{s}$ showed the highest results in the fresh weight of cabbage microgreens. The use of higher LED light intensity is thought to be able to increase the growth of red cabbage microgreens. This is in line with the research of Putri *et al.* (2021) blue LED power of 15 watts (3, 9, and 15 watts) gave the highest results for the growth of pakcoy microgreens such as many stems, number of leaves, and plant height, which can affect the fresh weight of plants. Based on research at 18 watts of power (equivalent to 119,3 $\mu\text{mol}/\text{m}^2/\text{s}$ PPFD) produced the highest crown fresh weight followed by 12 watts of power, and the lowest was 15 watts. This is reinforced by the research of Flores *et al.* (2024) red cabbage microgreens low intensity treatment (120 $\mu\text{mol}/\text{m}^2/\text{s}$) gave the highest fresh weight of 510,2 g/m² not significantly different from high intensity (210 $\mu\text{mol}/\text{m}^2/\text{s}$) of 482,7 g/m², and the lowest intensity medium (160 $\mu\text{mol}/\text{m}^2/\text{s}$) of 432,7 g/m².

Selenium biofortification treatment with different concentrations did not have a significant effect on the fresh weight of red cabbage microgreens (Table 3). Selenium tends to focus on bioactive content, so that the fresh weight of microgreens canopy can decrease. This is in accordance with the opinion of Naseem *et al.* (2021) which states that selenium administration can reduce bioactive pigments in plants because it is relevant to the inhibition of the growth system. The application of selenium showed significant results in bioactive components, indicating that selenium plays a role in improving the quality of the plant. This is in line with the opinion of Islam *et al.* (2020) selenium enrichment in wheat microgreens has no effect on plant height and weight due to competition between selenium and essential ion transporters contained in the growing medium.

Table 3. Fresh Weight of Red Cabbage Microgreens under Blue LED Power Treatment and Selenium Biofortification at 9 DAP.

Blue LED Power (watt)	Selenium Concentration (μM)				Average
	0	20	40	60	
	----- (g) -----				
12	1,87	2,09	1,79	2,12	1,97b
15	1,68	1,65	1,73	1,64	1,67c
18	1,92	1,98	2,19	2,27	2,09a
Average	1,82	1,91	1,90	2,01	

Notes: Numbers followed by different superscripts in the mean column indicate significantly different according to duncan's test ($p < 0,05$).

Table 4. Dry Weight of Red Cabbage Microgreens in Blue LED Power Treatment and Selenium Biofortification at 9 DAP.

Blue LED Power (watt)	Selenium Concentration (μM)				Average
	0	20	40	60	
	----- (g) -----				
12	0,08	0,07	0,09	0,07	0,08
15	0,10	0,09	0,08	0,09	0,09
18	0,08	0,09	0,09	0,07	0,08
Average	0,08	0,08	0,08	0,07	

3.4 Dry Weight of Microgreens

The results of analysis of variance showed that blue LED power treatment had no effect on the dry weight of red cabbage microgreens. Selenium biofortification treatment did not affect the dry weight of red cabbage microgreens. There was no interaction between blue LED power treatment and selenium biofortification on the dry weight of red cabbage microgreens presented in Table 4.

Table 4 shows that the difference in blue LED power has no significant effect on the dry weight of red cabbage microgreens. This is in line with the research of Ying *et al.* (2020) giving microgreens kale, arugula, and mustard blue light intensity range of 15,7 – 91,6 $\mu\text{mol}/\text{m}^2/\text{s}$ did not give significant results on dry yield. Dry weight on microgreens can be influenced by the high and low light intensity given. The results in the study showed the highest dry weight at 15 watts of blue LED power (equivalent to 83,2 $\mu\text{mol}/\text{m}^2/\text{s}$ PPFD) of 0,09 g and decreased with the low intensity of light given by about 1%. This is reinforced by the research of Flores *et al.* (2024) giving lower light intensity in the range of 210 - 120 $\mu\text{mol}/\text{m}^2/\text{s}$ decreased the dry weight of green cabbage microgreens by about 10% from 64,2 g/m^2 to 50,9 g/m^2 .

Selenium biofortification treatment with different concentrations did not significantly affect the dry weight of red cabbage microgreens (Table 4). This is reinforced by the research of Tavan *et al.* (2024) selenium enrichment method through foliar application of kale microgreens did not give significant results on dry matter of several concentrations with a minimum result of 4,21 g/100 g fresh weight of 10 μM Se and the highest 40 μM Se 5,45 g/100 g fresh weight. Biofortification with selenium had results that did not differ much between the control and higher concentrations. This is in line with the research of Pannico *et al.* (2020) Se application at several concentrations (0, 8, and 16 μM) did not give significantly different results in microgreens coriander, green and purple basil, and tatsoi. Selenium given to plants, especially on a micro scale, has a focus on improving nutritional quality and the results vary. This is in accordance with the opinion of D'Amato *et al.* (2020) Se biofortification treatment method has an effect in increasing Se content, but the results vary which is determined by species, dose, application time, concentration, and Se source.

3.5 Biomass Water Content

The result of analysis of variance shows that blue LED power treatment affects the biomass water content of red cabbage microgreens. Selenium biofortification treatment did not affect the biomass water content of red cabbage microgreens. There was no interaction between blue LED power treatment and selenium biofortification on the biomass water content of red cabbage microgreens presented in Table 5. Table 5 shows that different blue LED power significantly affected the biomass water content of red cabbage microgreens. The blue LED power of 18 watts (equivalent to 119,3 $\mu\text{mol}/\text{m}^2/\text{s}$ PPFD) produced the highest biomass water content value, but was not significantly different from the blue LED power of 12 watts (equivalent to 69,0 $\mu\text{mol}/\text{m}^2/\text{s}$ PPFD).

Table 5. Biomass Water Content of Red Cabbage Microgreens under Blue LED Power Treatment and Selenium Biofortification 9 DAP.

Blue LED Power (watt)	Selenium Concentration (μM)				Average
	0	20	40	60	
	----- (%) -----				
12	95,91	96,47	95,11	96,53	96,00a
15	93,86	94,70	95,12	94,21	94,47b
18	95,88	95,62	95,72	96,97	96,05a
Average	95,22	95,60	95,32	95,90	

Notes: Numbers followed by different superscripts in the mean column indicate significantly different according to duncan's test ($p < 0,05$).

Table 6. Chlorophyll A, Chlorophyll B, and Total Chlorophyll Content of Red Cabbage Microgreens under Blue LED Power Treatment and Selenium Biofortification at 9 DAP.

Parameters	Blue LED Power (watt)	Selenium Concentration (μM)				Average
		0	20	40	60	
		----- (mg/g) -----				
Chlorophyll A	12	2,56	3,54	3,12	2,90	3,03
	15	2,92	3,28	2,53	3,30	3,01
	18	3,54	3,82	3,55	2,81	3,43
Average		3,01	3,55	3,01	3,00	
Chlorophyll B	12	1,09	1,51	1,41	1,20	1,31
	15	1,22	1,35	1,25	1,43	1,31
	18	1,60	1,66	1,47	1,15	1,47
Average		1,30	1,51	1,38	1,26	
Total Chlorophyll	12	3,65	5,05	4,53	4,10	4,34
	15	4,14	4,63	3,78	4,73	4,32
	18	5,13	5,48	5,02	3,97	4,90
Average		4,31	5,05	4,44	4,27	

High LED light intensity will cause a decrease in biomass water content in plants, because it is suspected that biomass water content is influenced by environmental factors. This is in accordance with the opinion of Brazaitytė *et al.* (2021) that blue light with some intensity is able to fix CO_2 and induce stomatal opening. Biomass water content is related to fresh weight of microgreens, where the results of the 18 watt blue LED power study produced the highest biomass water content and the lowest 15 watts. The results on biomass water content are the same as the results of fresh weight of microgreens. This is in accordance with the research of Flores *et al.* (2024) green cabbage microgreens given high light intensity produced an average fresh weight of $385,5 \text{ g/m}^2$, followed by low intensity $383,6 \text{ g/m}^2$, and medium intensity 349 g/m^2 .

Selenium biofortification treatment with different concentrations had no significant effect on the biomass water content of red cabbage microgreens (Table 5). This is in accordance with the opinion of He *et al.* (2020) selenium enrichment of broccoli sprouts has a negative effect on growth, thus reducing hypocotyl length, fresh weight, and water content. The insignificant results of the study suggest that selenium is a micronutrient that does not directly play a role in biomass water content. This is in accordance with the opinion of Ikram *et al.* (2024) selenium is responsible for maintaining balance and protecting plants from oxidative stress derived from free radicals because it has a function as an antioxidant.

3.6 Chlorophyll Content

The results of analysis of variance showed that blue LED power treatment had no effect on chlorophyll a, chlorophyll b, and total chlorophyll levels of red cabbage microgreens. Selenium biofortification treatment had no effect on chlorophyll a, chlorophyll b, and total chlorophyll content of red cabbage microgreens. There was no interaction between blue LED power treatment and selenium biofortification on chlorophyll a, chlorophyll b, and total chlorophyll content of red cabbage microgreens presented in Table 6.

Table 6 shows that the difference in blue LED power has no significant effect on the chlorophyll content of red cabbage microgreens. The use of 18 watts of blue LED power resulted in the highest chlorophyll a, b and total content compared to 12 and 15 watts, although the difference was not statistically significant. This suggests that the higher LED power applied, the higher the chlorophyll content. This is reinforced by the research of Lobiuc *et al.* (2017) giving white light and a combination of red and blue intensity of 120 $\mu\text{mol}/\text{m}^2/\text{s}$ did not give significant results on chlorophyll a, chlorophyll b, and carotenoid pigments of red and green basil microgreens. This is in line with the research of Trandel-Hayse *et al.* (2025) red spinach microgreens treated with a combination of 300 $\mu\text{mol}/\text{m}^2/\text{s}$ PPFD lamps did not have significant results on the results of chlorophyll a, chlorophyll b, and total chlorophyll. The high and low content of chlorophyll in plants is influenced by the amount of light intensity given because it affects the photosynthesis process. This is in accordance with the opinion of Mardiyani *et al.* (2023) the reduced chlorophyll content of plants is caused by giving too high light intensity, so that the leaf temperature increases and the stomata close and some chlorophyll is damaged.

Selenium biofortification treatment with different concentrations did not significantly affect the chlorophyll content of red cabbage microgreens (Table 6). The use of selenium at a concentration of 20 μM resulted in the highest chlorophyll a, b, and total contents compared to concentrations of 0, 40, and 60 μM , although the difference was not statistically significant. This is reinforced by the research of Viltres-Portales *et al.* (2024) selenium biofortification with a concentration of 20 $\mu\text{mol}/\text{L}$ was not significant on chlorophyll b and total chlorophyll of kohlrabi microgreens compared to the control. Chlorophyll levels in microgreens can be increased through biofortification with selenium. This is in accordance with the opinion of Lanza and Reis, (2021) that chlorophyll biosynthesis in microgreens can be influenced by biofortification with selenium through transpiration chain electron flow, so that it can protect chloroplast enzymes and produce reactive oxygen species (ROS).

3.7 Carotenoid Content

The result of analysis of variance shows that blue LED power treatment does not affect the carotenoid content of red cabbage microgreens. Selenium biofortification treatment affects the carotenoid content of red cabbage microgreens. There is no interaction between blue LED power treatment and selenium biofortification on carotenoid content of red cabbage microgreens presented in Table 7. Table 7 shows that the difference in blue LED power has no significant effect on the carotenoid content of red cabbage microgreens. The use of blue LED power at 18 watts produced the highest carotenoid content compared to 12 and 15 watts, although the difference was not statistically significant. This is in accordance with the research of Ying *et al.* (2021) giving blue light intensity with different proportions (5 - 30%) did not give significant results on the total carotenoids of red cabbage microgreens, arugula, kale, and mustard greens. Higher blue light intensity in other studies also did not have a significant effect on the carotenoid content of microgreens. This is in accordance with the research of Lobiuc *et al.* (2017) blue light with a dose range of 33 - 67% did not give significant results on the total carotenoid concentration of basil microgreens. Carotenoids act as an antidote to free radicals because they are compounds that play a role in increasing antioxidant activity. This is in accordance with the opinion of Banerjee and Roychoudhury, (2019) the

administration of selenium at low doses is useful in preventing the buildup of Reactive Oxygen Species (ROS) as a stress regulator, whereas at high doses selenium functions in pro-oxidants that can increase ROS and cause lipid peroxidation.

Selenium biofortification treatment with different concentrations significantly affected the carotenoid content of red cabbage microgreens (Table 7). Selenium biofortification with a concentration of 20 μM had the best results (134,74 mg/g) compared to the control as well as higher concentrations. This agree with Viltres-Portales *et al.* (2024) that selenium mixture of sodium selenate and sodium selenite of 20 $\mu\text{mol/L}$ was effective in increasing total carotenoids to 133 mg/100g on kale microgreens. Selenium administration with low concentrations can increase the pigment content in a plant. This is in accordance with result by He *et al.* (2020) selenium enrichment in broccoli sprouts is able to increase carotenoid content caused by mitigating photoinhibition in the photosynthetic apparatus through the xanthophyll cycle.

3.8 Total Anthocyanins

The result of analysis of variance shows that blue LED power treatment affects the total anthocyanins of red cabbage microgreens. Selenium biofortification treatment affects the total anthocyanins of red cabbage microgreens. There is an interaction between blue LED power treatment and selenium biofortification on the total anthocyanins of red cabbage microgreens presented in Table 8. Table 8 shows that there is an interaction between different blue LED power and selenium biofortification concentration on total anthocyanins of red cabbage microgreens. The blue LED power of 18 watts combined with selenium concentration of 40 μM significantly increased the total anthocyanins of red cabbage microgreens compared to the blue LED power of 12 and 15 watts. The orthogonal polynomial test results of the interaction between different selenium biofortification concentrations at 12, 15, and 18 watts of blue LED power on total anthocyanins showed that the quadratic curve graph (Fig 1).

Table 7. Carotenoid Content of Red Cabbage Microgreens under Blue LED Power Treatment and Selenium Biofortification at 9 DAP.

Blue LED Power (watt)	Selenium Concentration (μM)				Average
	0	20	40	60	
	----- (mg/g) -----				
12	106,28	134,93	115,74	112,09	117,26
15	109,32	126,47	95,25	118,70	112,44
18	127,88	142,82	125,83	102,69	124,81
Average	114,49b	134,74a	112,27b	111,16b	

Notes: Numbers followed by different superscripts in the mean row indicate significantly different according to duncan's test ($p < 0,05$).

Table 8. Total Anthocyanins of Red Cabbage Microgreens under Blue LED Power Treatment and Selenium Biofortification at 9 DAP.

Blue LED Power (watt)	Selenium Concentration (μM)				Average
	0	20	40	60	
	----- (mg/L) -----				
12	3,95g	5,46fg	7,13ef	4,65g	5,30c
15	8,18e	11,13d	12,94d	7,18ef	9,86b
18	13,64d	21,21b	36,76a	17,03c	22,16a
Average	8,59d	12,60b	18,94a	9,62c	

Notes: Numbers followed by different superscripts in column or row means and interaction matrix indicate significantly different according to duncan's test ($p < 0,05$).

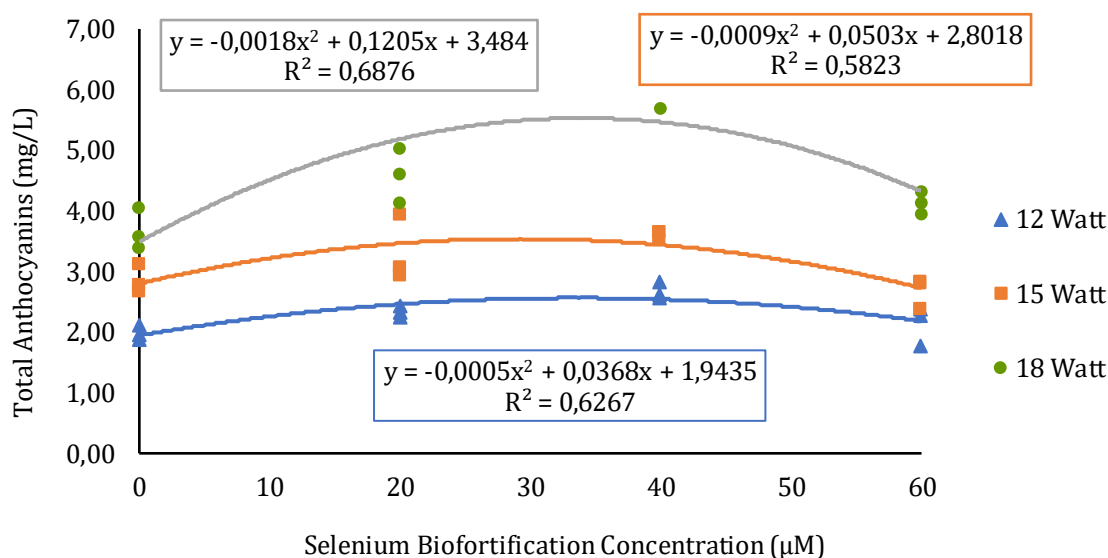


Fig 1. Orthogonal Polynomial Graph of Interaction between Blue LED Power and Selenium Biofortification on Total Anthocyanins.

The orthogonal polynomial test results of the interaction between different selenium biofortification concentrations at 15 watts blue LED power on total anthocyanins showed that the quadratic curve graph. The 12 watt blue LED power treatment at different selenium concentrations was able to increase the lowest total anthocyanins compared to 15 and 18 watts power. The 12 watt blue LED power treatment increased the total anthocyanins of red cabbage microgreens at a selenium concentration of 40 μM , but was not significantly different from the selenium concentration of 20 μM . Meanwhile, the addition of selenium with a concentration of 20 μM gave results that were not significantly different from the concentration of 60 μM or 0 μM (control).

Giving different selenium concentrations at 15 watts LED power to total anthocyanins showed a quadratic curve graph. The treatment of 15 watts blue LED power combined with 40 μM selenium concentration resulted in a relatively high anthocyanin content in red cabbage microgreens, although not significantly different from the 20 μM concentration. This is reinforced by the research of Cowden *et al.* (2024) giving blue light intensity (55,75 vs 9,81 W/m^2) resulted in an increase in anthocyanin microgreens kohlrabi average of 14,94 higher than 6,63 mg/L/g . Selenium biofortification with concentrations of 0 μM (control) and 60 μM gave results that were not significantly different.

The treatment of various levels of selenium concentration at 18 watts blue LED power on total anthocyanins showed a quadratic graph curve. The blue LED power of 18 watts gave the highest results of total anthocyanins of red cabbage microgreens at different selenium concentrations. The 18 watt blue LED power combined with 40 μM selenium concentration effectively increased the highest total anthocyanin content of red cabbage microgreens. It is suspected that the provision of light with a higher power of 18 watts, the higher the intensity of the blue LED produced (69.0 to 119,3 $\mu\text{mol/m}^2/\text{s}$), the anthocyanin content tends to increase. Giving different selenium concentrations at 18 watts LED power to total anthocyanins showed a linear curve graph. This is confirmed by Islam *et al.* (2020) wheat microgreens under LED light intensity of 150 $\mu\text{mol/m}^2/\text{s}$ combined with 0,25 mg/L sodium selenite increased total anthocyanins 11,02 $\mu\text{g/mL}$. Increasing the selenium concentration to the optimal level of 40 μM was able to increase the highest anthocyanin levels, followed by a concentration of 20 μM , then 60 μM , and the lowest result was 0 μM (control). It is suspected that selenium enrichment at a concentration of 40 μM helps improve the plant defense system and stimulates anthocyanin production. This is reinforced by the research of He *et al.* (2020) Se enrichment in broccoli sprouts increased anthocyanin content by 9,13 – 9,88 $\mu\text{g/g}$ compared to

not given Se (7,29 µg/g) by reducing chlorophyll content. The addition of selenium with optimal point concentration in micro-scale or early growth plants such as microgreens can increase pigment content, namely total anthocyanins. Selenium enrichment given at high concentrations can trigger toxicity, whereas the control treatment did not show an increase in anthocyanin content. Selenium biofortification with higher concentrations in red cabbage microgreens, namely 60 µM, has a risk of toxicity that can reduce anthocyanin levels. This is in accordance with the opinion of Hasanuzzaman *et al.* (2020) that excessive selenium concentrations can trigger toxic effects because selenium plays a role in changes in structural and protein function, thus triggering oxidative stress and disrupting plant metabolic processes.

4. CONCLUSIONS

Based on the research that has been done, it can be concluded that the treatment of 18 watts of blue LED power is effective for increasing fresh weight and water content of red cabbage microgreens. Selenium biofortification treatment with a concentration of 20 µM is effective in increasing carotenoid content. Blue LED power of 18 watts combined with selenium concentration of 40 µM can increase the highest total anthocyanin content.

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