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Effects of LED Light Duration and Growing Media on Growth of Kale (*Brassica oleracea* var. Acephala) Microgreens

Hafizh Dzaky Raihan[1,*], Susiyanti[1], Sulastri Isminingsih[1], Alfu Laila[1]

Abstract

Kale (*Brassica oleracea* var. Acephala) is a plant that has good adaptability to various environmental conditions, and can be cultivated throughout the year with relatively simple cultivation. This study investigated the effects of LED light exposure duration (9, 12, and 15 hours/day) and various growing media (cocopeat, rice husk charcoal, and rockwool) on the growth of kale microgreens (*Brassica oleracea* var. Acephala) in a controlled indoor environment. Using a split-plot design, key parameters including plant height, leaf number, leaf greenness index, and fresh weight were evaluated over 14 days after planting (DAP). Results indicated that cocopeat significantly enhanced plant height (up to 10.76 cm) and fresh weight (0.55 g), while rockwool promoted superior leaf greenness (22.10 units) and leaf count (2.22 leaves). Longer light exposure (15 hours) improved leaf number, greenness, and fresh weight, with significant interactions observed in leaf count. These findings highlight optimal conditions for urban farming, supporting efficient nutrient-rich microgreen production amid declining agricultural land.

Keywords: 15 Hours, Cocopeat, Leaf Greenness Index, Rockwool, Urban Farming

1. Introduction

Kale (*Brassica oleracea* var. Acephala) is widely recognized as a superfood owing to its exceptionally high content of nutrients and bioactive compounds. This vegetable is particularly rich in vitamins, including vitamin A and several B-complex vitamins such as B1 (thiamine), B2 (riboflavin), and B3 (niacin). In addition, kale is an excellent source of vitamin C. Notably, it contains isothiocyanate compounds, especially sulforaphane, which has attracted considerable research attention due to its potential anticancer properties. The synergistic combination of these essential nutrients and bioactive compounds makes kale a preferred dietary choice for individuals seeking to promote a healthy lifestyle and prevent chronic diseases (Laki *et al*., 2021).

Given these aforementioned advantages, the popularity of kale is expected to rise progressively over time. However, according to data from the Central Statistics Agency (BPS, 2023), kale production declined from 1,503,798 tons in 2022 to 1,399,005 tons in 2023. The reduction in agricultural land is considered one of the primary factors contributing to the decreased production of vegetables such as kale (Pratama *et al*., 2022).

Urban farming holds considerable potential to address the constraints on cultivable land in urban areas. This approach utilizes limited spaces, such as residential yards, for food production, thereby serving as a viable alternative amid the scarcity of conventional agricultural land in cities (Sebayang *et al*., 2022). Microgreens represent a prominent example of urban farming practices. The cultivation of these young plants offers a practical and space-efficient method to enhance the nutritional intake of urban populations, while simultaneously promoting healthy lifestyles through straightforward and resource-efficient planting techniques.

Microgreens are harvested at an early developmental stage, typically 7–14 days after sowing. They are considered a superior alternative to sprouts due to their higher nutrient density and more intense flavor and aroma (Ebert, 2022). Furthermore, microgreens tend to contain elevated concentrations of phytochemicals, minerals, and vitamins compared to their mature counterparts (Rohmanna

*Correspondence: hafizhdzakyraihan@gmail.com
1) Universitas Sultan Ageng Tirtayasa - Jl. Raya Palka No. Km 3, Sindangsari, Kota Serang, Banten 42163. Indonesia

et al., 2023). Consequently, the consumption of microgreens can enhance dietary nutritional quality and exert beneficial effects on consumer health. The heightened nutrient content in microgreens is attributed to catabolic processes that occur during the 7–21-day growth period (Lutfi *et al*., 2022).

The cultivation of microgreens is typically conducted in controlled indoor environments. Consequently, alternatives to natural sunlight are required. A commonly employed solution is the utilization of artificial lighting, particularly through Light Emitting Diode (LED) lamps. LED technology enables precise regulation and optimization of light exposure for microgreen plants, effectively substituting the role of sunlight in their growth processes. LED lamps represent energy-efficient light sources that are readily controllable and produce minimal heat, thereby making them highly suitable for microgreens cultivation (Wiliem & Zumani, 2025).

According to a study by Pangestika *et al*. (2022), photoperiods of 12 and 16 hours per day resulted in maximum plant height and fresh weight in red cabbage microgreens (*Brassica oleracea* var. capitata f. rubra). Liu *et al*. (2022) reported that a 14-hour daily photoperiod produced the highest fresh weight in kailan microgreens (*Brassica oleracea* var. alboglabra), while photoperiods of 14 and 20 hours per day yielded the maximum fresh weight in cabbage microgreens (*Brassica oleracea* var. capitata). In this study, the novelty lies in evaluating the interaction between LED light exposure duration and different types of growing media on various growth parameters of kale microgreens, as well as in analyzing their effects on the leaf greenness index, which has received limited attention in previous studies.

The growing medium also plays a pivotal role in microgreens cultivation. According to Putra *et al*., (2025) a growing medium provides a place for plant roots to grow and provides the nutrients needed for plant growth and development. For a growing medium to be effective, it must meet several important criteria, such as the ability to bind and retain water and nutrients, have good aeration and drainage, and be disease-free.

Variations in planting substrates significantly influence the availability of water and nutrients, thereby directly affecting plant growth and the biosynthesis of phytochemical compounds (Sisriana *et al*., 2021). According to research conducted by Adiwijaya *et al*., (2024), rockwool as a growing medium yielded the optimal plant height at 14 days after planting (DAP), whereas rice husk charcoal medium produced the best results in terms of leaf number, stem diameter, and fresh weight in kale (*Brassica oleracea* var. acephala). This opinion is in line with the statement put forward by Charloq (2024), that rice husk charcoal is a good organic material for maintaining soil moisture because, when added to the soil, the charcoal binds water and then releases it into the micropores to be absorbed by plants. Septirosya *et al*. (2024) reported that cocopeat and vermiculite media achieved maximum plant height in red cabbage microgreens (*Brassica oleracea* var. capitata f. rubra), while rockwool medium resulted in the highest fresh weight in the same species at 14 DAP. Furthermore, Sulistya (2021) demonstrated that cocopeat medium produced maximal plant height and fresh weight in broccoli microgreens (Brassica oleracea var. italica) at 20 DAP.

Based on the preceding discussion, the objective of this study is to examine the effects of LED light exposure duration and different planting media on the growth of kale microgreens (*Brassica oleracea* var. acephala). This research is urgently warranted given the significant decline in kale production in Indonesia due to the shrinkage of agricultural land, while demand for kale as a nutrient-dense superfood continues to rise to support urban food security and healthy lifestyles. Accordingly, the findings of this study are expected to offer practical solutions through efficient indoor cultivation techniques that address land constraints and improve accessibility to highly nutritious vegetables.

2. Material and Methods

This study was conducted in Ciakar Village, Panongan District, Tangerang Regency, Banten Province, Indonesia. The location used has an altitude of 40 meters above sea level with coordinates (6°15′35″S, 106°31′11″E), and at the Agroecology Laboratory, Faculty of Agriculture, Sultan Ageng Tirtayasa University. The research was carried out in November 2025. The equipment utilized in this study included 20-watt LED lamps, a ruler, a thermo-hygrometer, plastic trays, 12 oz plastic cups, cardboard boxes (30 × 30 × 30 cm), a smartphone camera, a SPAD, a digital balance, scissors, a spray bottle, a lux meter, a digital vernier caliper, and stationery. The materials employed comprised seeds of kale (Brassica oleracea var. acephala) cultivar 'Dwarf Blue Curled Scotch', cocopeat, rice husk charcoal, rockwool, label paper, and water.

The parameters observed in this study encompassed plant height, number of leaves, leaf greenness index, and plant fresh weight.

The experimental design used in this study was a split plot design (RAL) consisting of the main plot, namely the duration of LED light exposure (L) which consists of 3 levels: L1 = 9 hours, L2 = 12 hours, and L3 = 15 hours. The subplot is the planting medium (M) which consists of 3 levels: M1 = Cocopeat planting medium, M2 = Rice husk charcoal planting medium, and M3 = Rockwool planting medium. Thus, there were 9 treatment combinations, each repeated 3 times, so that in this study there were 27 experimental units.

To determine the effect of the treatment, an analysis of variance (F-test) was conducted at the 5% level. If the analysis of variance results indicate a significant or very significant effect, further testing was conducted. In this study, the Duncan Multiple Range Test (DMRT) was used at the 5% level, processed using the DSAASTAT ver. 1.514 application.

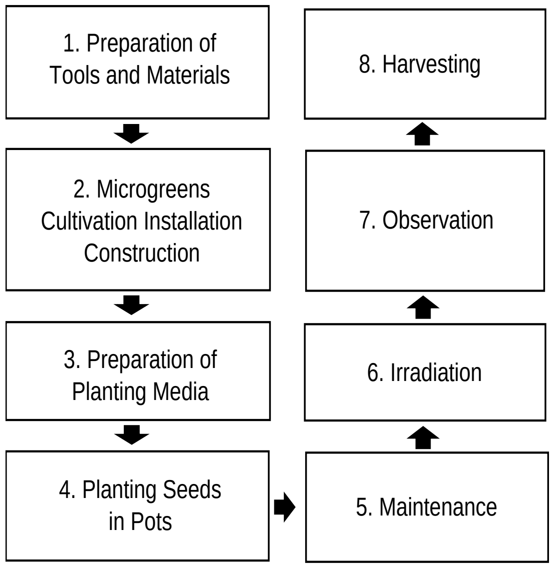

Figure 1. Research flow diagram

3. Results and Discussion

3.1. Plant Height

The analysis of variance revealed that the duration of LED light exposure had no significant effect. In contrast, the type of growing medium exerted a significant effect on the height of kale microgreens. Furthermore, no significant interaction was observed between the two treatments. The mean plant heights of kale microgreens from 6 to 14 DAP are presented in Table 1.

Cocopeat as a growing medium exerted a highly significant effect on the height of kale microgreens from 6 to 14 DAP. Cocopeat contains a diverse array of macro- and micronutrients, including potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na), and other essential minerals. Potassium (K) is the most quantitatively dominant element among the nutrients it contains. According to Wan *et al*. (2024), sufficient and stable potassium (K) levels in the growing medium play a critical role in promoting stem cell elongation, thereby significantly enhancing overall plant height growth.

Table 1. Mean plant height (cm) of kale at 6–14 DAP under different durations of LED light exposure and various growing media.

LED Light Exposure	**Growing Media**			**Mean**
	M1 (Cocopeat)	**M2 (Rice husk charcoal)**	**M3 (Rockwool)**	
		...........................cm...........................		
6 DAP				
L1 (9 hours)	7,17 ± 0,53	6,48 ± 0,95	5,41 ± 0,47	6,36 ± 0,97
L2 (12 hours)	6,69 ± 0,67	6,31 ± 0,28	4,69 ± 0,47	5,89 ± 1,02
L3 (15 hours)	7,15 ± 0,75	5,96 ± 0,44	5,16 ± 0,26	6,09 ± 0,98
Mean	7,00 ± 0,62 a	6,25 ± 0,59 b	5,09 ± 0,48 c	
8 DAP				
L1 (9 hours)	8,31 ± 0,25	7,93 ± 0,35	7,12 ± 0,69	7,79 ± 0,67
L2 (12 hours)	8,65 ± 0,79	7,85 ± 0,13	6,57 ± 0,79	7,69 ± 1,07
L3 (15 hours)	8,31 ± 0,63	7,21 ± 0,45	7,02 ± 0,35	7,51 ± 0,74
Mean	8,42 ± 0,55 a	7,66 ± 0,45 b	6,90 ± 0,60 c	
10 DAP				
L1 (9 hours)	9,51 ± 0,63	8,66 ± 0,78	8,26 ± 1,21	8,81 ± 0,96
L2 (12 hours)	9,60 ± 1,10	8,56 ± 0,18	8,29 ± 0,32	8,82 ± 0,83
L3 (15 hours)	9,83 ± 1,04	8,27 ± 0,12	8,14 ± 0,55	8,75 ± 1,01
Mean	9,64 ± 0,83 a	8,50 ± 0,44 b	8,23 ± 0,69 b	
12 DAP				
L1 (9 hours)	10,21 ± 0,61	9,15 ± 0,84	8,83 ± 1,19	9,39 ± 1,01
L2 (12 hours)	10,24 ± 1,11	9,00 ± 0,21	8,62 ± 0,29	9,29 ± 0,94
L3 (15 hours)	10,29 ± 1,23	8,60 ± 0,12	8,53 ± 0,53	9,14 ± 1,09
Mean	10,24 ± 0,88 a	8,91 ± 0,50 b	8,66 ± 0,68 b	
14 DAP				
L1 (9 hours)	10,71 ± 0,67	9,59 ± 0,91	9,14 ± 1,15	9,81 ± 1,07
L2 (12 hours)	10,79 ± 1,19	9,24 ± 0,22	8,91 ± 0,22	9,65 ± 1,07
L3 (15 hours)	10,77 ± 1,36	8,93 ± 0,15	8,96 ± 0,61	9,55 ± 1,18
Mean	10,76 ± 0,96 a	9,25 ± 0,55 b	9,00 ± 0,67 b	

Note: Mean numbers followed by the same letter within the same row or column do not differ significantly according to the Duncan Multiple

Range Test (DMRT) at the 5% significance level.

Cocopeat exhibits a high cation exchange capacity (CEC). CEC measures the ability of soil or growing media to retain and gradually release essential nutrient cations, such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^{+}), ensuring sustained availability for root uptake. This supports stem cell elongation and vertical plant growth, particularly during the vegetative phase. These properties align with the observations of Shafira *et al*. (2021), who reported that cocopeat has excellent water absorption capacity and the ability to store and release nutrients for plants.

Based on the study conducted by Sisriana *et al*. (2021), the use of cocopeat as a growing medium resulted in the highest plant height at 10 days after sowing (DAS), with an average value of 8.16 cm, indicating that cocopeat was the most effective growing medium compared to other media.

3.2. Number of Leaves

The analysis of variance revealed a significant interaction between the two treatments, which exerted a significant effect at 12 and 14 DAP. The mean number of leaves in kale microgreens is presented in Table 2.

Table 2. Mean number of leaves (leaves) in kale at 12–14 DAP under different durations of LED light exposure and various growing media.

LED Light Exposure	Growing Media			Mean
	M1 (Cocopeat)	M2 (Rice husk charcoal)	M3 (Rockwool)	
	..........................leaves..........................			
12 DAP				
L1 (9 hours)	2,00 ± 0,00 c	2,11 ± 0,19 bc	2,22 ± 0,19 ab	2,11 ± 0,17 ab
L2 (12 hours)	2,00 ± 0,00 c	2,00 ± 0,00 c	2,00 ± 0,00 c	2,00 ± 0,00 b
L3 (15 hours)	2,33 ± 0,00 a	2,00 ± 0,00 c	2,33 ± 0,00 a	2,22 ± 0,17 a
Mean	2,11 ± 0,17 ab	2,04 ± 0,11 b	2,18 ± 0,17 a	
14 DAP				
L1 (9 hours)	2,00 ± 0,00 d	2,11 ± 0,19 cd	2,22 ± 0,19 bc	2,11 ± 0,17 b
L2 (12 hours)	2,00 ± 0,00 d	2,00 ± 0,00 d	2,00 ± 0,00 d	2,00 ± 0,00 b
L3 (15 hours)	2,33 ± 0,00 ab	2,11 ± 0,19 cd	2,44 ± 0,19 a	2,29 ± 0,20 a
Mean	2,11 ± 0,17 b	2,07 ± 0,15 b	2,22 ± 0,23 a	

Note: Mean numbers followed by the same letter within the same row and column do not differ significantly according to the Duncan Multiple Range Test (DMRT) at the 5% significance level.

Based on the leaf number observations presented in Table 2, a significant interaction was detected between the two treatments, exerting a notable effect on the leaf number parameter in kale microgreens. The treatment combination of a 15-hour LED light duration and rockwool growing medium produced the optimal results at 14 DAP. This outcome can be attributed to the synergistic effects between extended LED light exposure, which promotes photosynthesis and carbohydrate accumulation to support leaf proliferation, and the inherent properties of rockwool—namely, optimal aeration, balanced water retention, and high sterility—that enable more efficient nutrient uptake compared to cocopeat and rice husk charcoal media. These findings are consistent with those of Manullang *et al*. (2019), who demonstrated that carbohydrates contribute to chlorophyll synthesis in developing leaves.

Aini *et al*. (2023) further reported that chlorophyll plays a crucial role in photosynthesis, generating the energy required for cellular processes such as division, expansion, and elongation. This facilitates the formation of new cells, thereby increasing leaf number. An additional factor influencing leaf development is the texture of the growing medium.

According to Valupi *et al*. (2021), the use of rockwool as a growing medium had a significant effect compared to cocopeat and vermiculite on the leaf number parameter of pakcoy microgreens (*Brassica rapa* L.), with an average value of 4.16 cm. Rockwool possesses a porous texture that provides firm root anchorage, resulting in more upright plant growth and enhanced light absorption by leaves from the LED source. This is corroborated by Muhiddin *et al*. (2023), who indicated that the porous structure of rockwool facilitates root proliferation and effective water absorption—capable of retaining up to 80% water—thereby supporting metabolic exchange processes that are postulated to improve overall plant growth and yield superior performance across measured parameters.

3.3. Leaf Greenness Index

The analysis of variance revealed that both the duration of LED light exposure and the type of growing medium exerted significant effects at 14 DAP. No significant interaction was observed between the two treatments. The mean leaf greenness indices of kale microgreens are presented in Table 3.

The 15-hour LED light exposure treatment yielded the highest mean leaf greenness index. This is presumably attributable to the extended duration of light exposure received by the plants, which significantly stimulated chlorophyll synthesis in the leaves.

Table 3. Mean leaf greenness index (units) of kale at 14 DAP under different durations of LED light exposure and various growing media.

LED Light Exposure	**Growing Media**			**Mean**
	M1 (Cocopeat)	**M2 (Rice husk charcoal)**	**M3 (Rockwool)**	
	..........................unit..........................			
14 DAP				
L1 (9 hours)	13,95 ± 1,53	16,27 ± 1,23	19,50 ± 3,52	16,57 ± 3,14 b
L2 (12 hours)	19,27 ± 0,82	18,38 ± 1,71	21,70 ± 4,51	19,78 ± 2,86 a
L3 (15 hours)	19,34 ± 0,99	18,81 ± 0,95	25,12 ± 1,75	21,09 ± 3,23 a
Mean	17,52 ± 2,86 b	17,82 ± 1,65 b	22,10 ± 3,87 a	

Note: Mean numbers followed by the same letter within the same row or column do not differ significantly according to the Duncan Multiple Range Test (DMRT) at the 5% significance level.

Based on the study by Sendari *et al*. (2023), a LED light exposure duration of 14 hours produced the best results compared to exposure durations of 6 and 10 hours for the leaf chlorophyll parameter of sunflower (*Helianthus annus*) microgreens, with an average value of 25.29 units. Photoperiod duration exerts a significant influence on chlorophyll biosynthesis in plant leaves. Optimal light intensity and duration promote more intensive chlorophyll formation, thereby enhancing the capacity for light energy capture and ultimately intensifying the overall photosynthetic rate. These findings align with those of Nugraheni *et al*. (2021), who identified photoperiod as a primary light-related factor regulating plant growth, development, and nutritional value. Similarly, Ikrarwati *et al*. (2020) reported that increased light intensity received by plants corresponds with elevated chlorophyll content, facilitating greater light energy capture and accelerating photosynthetic rates.

The rockwool growing medium produced the highest mean leaf greenness index compared to the other two media. This outcome is attributed to the porous structure of rockwool, which provides robust root anchorage, enabling plants to develop a more sturdy and upright habit. This stable root system optimizes leaf orientation, thereby facilitating maximal and uniform absorption of LED light across leaf surfaces, which in turn positively influences chlorophyll accumulation.

3.4. Fresh Weight

The analysis of variance indicated that both the duration of LED light exposure and the type of growing medium exerted significant effects at 14 DAP. No significant interaction was observed between the two treatments. The mean fresh weights of kale microgreens are presented in Table 4.

Table 4. Mean fresh plant weight (g) of kale at 14 DAP under different durations of LED light exposure and various growing media.

LED Light Exposure	**Growing Media**			**Mean**
	M1 (Cocopeat)	**M2 (Rice husk charcoal)**	**M3 (Rockwool)**	
	..........................g..........................			
14 DAP				
L1 (9 hours)	0,34 ± 0,10	0,28 ± 0,02	0,31 ± 0,12	0,31 ± 0,08 b
L2 (12 hours)	0,52 ± 0,13	0,36 ± 0,09	0,27 ± 0,007	0,39 ± 0,14 b
L3 (15 hours)	0,78 ± 0,15	0,47 ± 0,05	0,64 ± 0,08	0,63 ± 0,16 a
Mean	0,55 ± 0,22 a	0,37 ± 0,10 b	0,41 ± 0,19 b	

Note: Mean numbers followed by the same letter within the same row or column do not differ significantly according to the Duncan Multiple Range Test (DMRT) at the 5% significance level.

Based on the fresh weight observations presented in Table 5, the 15-hour LED light exposure treatment produced the highest mean fresh plant weight. Extended durations of light exposure intensify the photosynthetic rate in plants. The primary products of photosynthesis—chiefly carbohydrates and other organic compounds—serve as the main energy source for various metabolic processes. This energy is subsequently allocated to support the synthesis of new tissues, growth activities, and biomass accumulation in both vegetative and reproductive organs. These findings align with those of Ikrarwati *et al*. (2020), who reported a positive correlation between light intensity and photosynthetic rate, with higher photosynthetic activity correspondingly enhancing the fresh weight of microgreens. This finding is consistent with the results of Maseva *et al*. (2024), which demonstrated that an LED light exposure duration of 20 hours produced the highest average fresh weight in red spinach microgreens (*Amaranthus tricolor* L.), reaching 13.12 g.

The cocopeat growing medium treatment yielded the highest mean fresh plant weight compared to the other two media. According to Sisriana *et al.* (2021), cocopeat contains 0.31% nitrogen (N), providing microgreens grown in this medium with greater nutrient availability than those in rice husk charcoal or rockwool media. Increased nutrient uptake improves photosynthetic efficiency, resulting in higher production of carbohydrates and proteins, which in turn positively influences fresh plant weight.

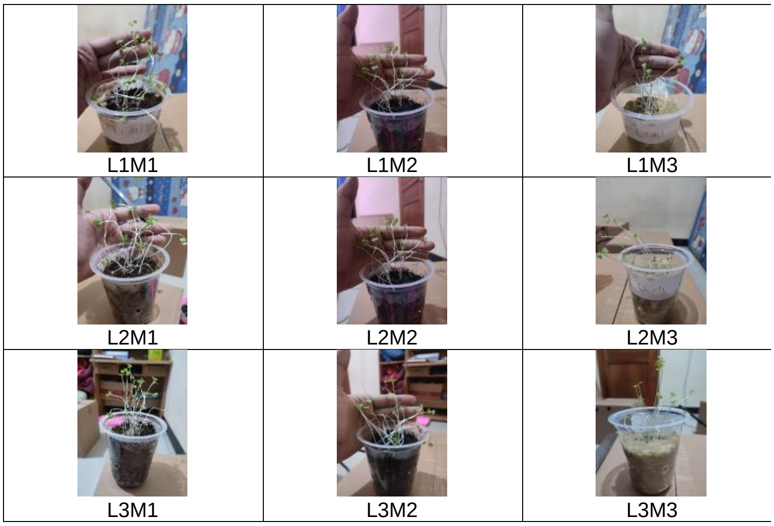

Figure 2. Research documentations

4. Conclusion

The results revealed a significant interaction between the duration of LED light exposure and the type of growing medium on the number of leaves in kale microgreens. The optimal interaction was achieved with the combination of a 15-hour daily photoperiod and rockwool as the growing medium. A light exposure duration of 15 hours produced the best results for the number of leaves parameter at 14 days after planting (DAP) (2.29 leaves), the leaf greenness index (21.09 units), and plant fresh weight (0.63 g). Meanwhile, cocopeat as a growing medium resulted in the highest plant height at 14 DAP (10.76 cm) and plant fresh weight (0.55 g).

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