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Analysis of the growth and yield of *Microgreens* of the *Brassica* sp. family on the effect of limited irradiation

Audina Tri Meiliansya*, Yayu Sri Rahayu, Nurcahyo Widyodaru Saputro
Universitas Singaperbangsa Karawang, Kabupaten Karawang, Indonesia
*Corresponding author: audina.meiliansya@gmail.com

ABSTRACT

Microgreens are a key concept in urban farming due to their ability to be grown easily, affordably, and efficiently in limited urban space, and offering high nutritional benefits. This study aims to determine the growth and yield of microgreens from the Brassica sp. family, which is cultivated under limited lighting conditions. This research was conducted from February to March 2025 at the laboratory of the Faculty of Agriculture, Singaperbangsa University, Karawang, located in Karawang Regency, West Java. This study employed an experimental method using a Split-Plot design within a Group Randomized Design framework, consisting of a main plot and a subplot. The main consisted of six levels of limited light exposure: indoor control, outdoor control, lighting at 60%, lighting at 50%, lighting at 40%, and lighting at 30%. The subplots were divided into three plant types: cauliflower, radish, and broccoli. Each treatment was repeated twice, resulting in a total of 36 experimental units. The effects of the treatment were analyzed using a variety of F-tests at the 5% significance level. When a significant interaction was detected, further analysis was conducted using the DMRT (Duncan's Multiple Range Test). The experimental results indicated a significant interaction between limited light exposure and plant type on the observed parameters of growth uniformity and plant height at 7 days after planting (DAP). The combination of lighting at 50% with broccoli plants provides the highest growth coherence value of 88%. In contrast, the highest value at 7 days after planting, measuring 6.55 cm, was observed in the lighting at 30% combined with broccoli plants.

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INTRODUCTION

The increasing population has led to a growing demand for housing, which in turn has triggered land-use conversion, posing a serious threat to food security. This is due to the reduction in local agricultural production caused by the conversion of farmland (Prabowo et al., 2020). One potential solution to this issue is the implementation of urban farming. Urban farming activities are also considered a solution for enhancing household food security and strengthening the body's immune system (Carolina et al., 2023). Urban farming practices can be carried out through microgreens cultivation—a simple, practical method rich in vitamins (Rizkiyah & Wijayanti, 2021).

Microgreens have gained popularity in recent years and are widely consumed as functional foods due to their high nutritional content and the presence of bioactive compounds, also known as secondary metabolites. Morphologically, microgreens consist of a small stem, cotyledon leaves, and two juvenile true leaves. However, not all young leafy vegetables are considered microgreens. These are generally collected later than sprouts and are smaller than baby greens (Partap et al., 2023). These immature plants are harvested between 7 and 21 days (depending on the variety). The nutritional content of microgreens is of particular interest for applications in public health awareness and human nutrition, especially in the prevention of malnutrition, inflammation, and other chronic diseases (Bhaswant et al., 2023).

Microgreens cultivation is considered practical and cost-effective as it can be done using trays, with or without planting media. Moreover, microgreens can be grown indoors or outdoors as they do not require direct sunlight (Renna et al., 2018). Even though microgreens can be easily grown, they present specific challenges. To enhance germination rates, seeds are typically pre-soaked before planting. During the germination process, the containers are placed in an environment with low humidity and adequate lighting (Singh et al., 2024). The quality, taste, nutritional content, aroma, and color of microgreens are influenced by the intensity, duration, and wavelength of light they receive (Kyriacou et al., 2016).

Mainly exploited are species belonging to the families Brassicaceae, Asteraceae, Chenopodiaceae, Apiaceae, and Cucurbitaceae. Bioactive content is prominent in species of somewhat acrid taste (e.g. Brassicaceae) (Xiao et al., 2012). This family includes broccoli, cabbage, kale, radish, cauliflower, mustard, and others. These microgreens are highly valued due to their rich nutritional content and bioactive compounds, including phenolics, glucosinolates, carotenoids, tocopherols, and ascorbic acid (Ramirez et al., 2020).

Lighting plays a critical role in the success of microgreens cultivation. These plants are sensitive to direct sunlight and require indirect light with high intensity (12–18 hours per day) to support optimal growth (As'adiya & Murwani, 2021). Providing optimal lighting conditions for plants at specific developmental stages can help reduce energy loss and optimize plant growth (Han et al., 2017).

Light is a critical environmental factor that influences plant growth and development, ranging from seed germination to flowering and fruiting (Yang et al., 2022). Photosynthesis can be enhanced by providing optimal environmental conditions, including appropriate light intensity and the wavelength of light received by the plant (Leister, 2023). Agronomically, new lighting technologies, such as Light-Emitting Diode (LED), have the potential to meet the fluence and wavelength requirements of plants, while allowing specific wavelengths to be enriched, thereby supplying the light quantity and quality essential for different growth phases (Darko et al., 2014).

Thus, lighting plays a crucial role in the photosynthesis process, which converts light energy into chemical energy stored in organic compounds. Insufficient light can disrupt photosynthesis and hinder plant growth, even though the sunlight requirements vary depending on the plant species. However, if the light intensity is too high, chlorophyll can become damaged (Pramadana et al., 2021).

Adjusting light intensity using shade nets (shade net) is an effective solution for creating a more balanced growing environment. Appropriate light intensity enhances carbon dioxide absorption, water usage efficiency, and nutrient uptake from the soil, ultimately boosting plant growth and productivity (Taiz et al., 2023).

Therefore, a system was developed to control the amount of light received by the plants. To regulate the intensity of sunlight, shade nets (shade net) are used to reduce the light intensity reaching the plants. By adjusting the light intensity appropriately, this system is expected to help manage the plants' sunlight requirements and optimize the growth and yield of microgreens.

The objective of this study is to identify the optimal limited lighting conditions that promote the highest growth performance and yield of various microgreens species within the *Brassica* family.

METHOD

The experiments were conducted at Building A of the Faculty of Agriculture, Universitas Singaperbangsa Karawang. Microgreens of radish, cauliflower, and broccoli were cultivated using soil as the growing medium in plastic containers measuring 18 × 9 × 6 cm. The cultivation of microgreens was carried out under controlled light conditions using shade nets (shade net) with varying pore densities. The light treatments included indoor control, outdoor control, 60% light intensity, 50% light intensity, 40% light intensity, and 30% light intensity.

The shade nets were used to simulate limited light exposure for the plants. For instance, the use of a 40% shade net corresponds to plants receiving 60% of the natural light, as measured using a lux meter. Specifically, the 60% light intensity treatment utilized a 40% density shade net, resulting in a light intensity of 2.326 lux. The 50% light intensity treatment utilized a 50% density shade net, resulting in a light intensity of 1.495 lux. The 40% light intensity treatment utilized a 60% density shade net, resulting in a light intensity of 1.365 lux. The 30% light intensity treatment used a 70% density shade net, resulting in a light intensity of 341 lux.

Statistical analysis was performed using analysis of variance (ANOVA) at a 5% significance level. If significant differences were observed, further analysis was conducted using Duncan's Multiple Range Test (DMRT) at the 5% significance level.

RESULTS AND DISCUSSION

Germination Uniformity

Based on the DMRT results at the 5% level (Table 1), a significant interaction was observed between limited irradiation and plant type on the germination uniformity of *Brassica sp.* microgreens. Treatment t_4 (lighting 50%, 1,495 lux) combined with broccoli (m_3) showed the highest germination uniformity at 88%, while t_4 and t_5 (lighting 50% and lighting 40%) on cauliflower (m_1) showed 85.5%. Radish (m_2) under outdoor control (t_2) achieved 83%. These results indicate that different irradiation and plant types can impact germination uniformity. Aligning with findings by (Dias et al., 2020), who emphasized that there are several types of agriculture and forest plants whose seed germination phases are triggered by light, while others require low light intensity. In addition, (Dubey & Nain, 2024) stated that each species requires distinct environmental conditions to achieve optimal growth at every stage of its development.

The highest germination uniformity observed t_4 lighting treatment suggests that 50% irradiation (light intensity 1.495 lux) provides adequate light for microgreens growth. This result is supported by the findings of (Balázs et al., 2023), which show that germination uniformity for microgreens (peas) is influenced by light intensity. Moreover, (Utami, 2016) stated that light intensity can also enhance the growth rate; however, excessively high or low light intensities may also inhibit photosynthesis and plant growth.

Table 1. The Effect of Interaction Between Microgreens Family Brassica Sp. and Limited Irradiation on the Germination Uniformity

Treatments	m_1 (Cauliflower)	m_2 (Radish)	m_3 (Broccoli)
t_1 (Indoor control)	62.5 d A	43.5 c C	48.5 e B
t_2 (Outdoor control)	81 b A	83 a A	81.5 b A
t_3 (Lighting 60%)	36.5 e C	76 b A	65.5 d B
t_4 (Lighting 50%)	85.5 a A	74.5 b B	88 a A
t_5 (Lighting 40%)	85.5 a A	76.5 b B	71.5 c C
t_6 (Lighting 30%)	74 c A	76 b A	74.5 c A

Plant Height

The DMRT results at the 5% level (Table 2) show a significant interaction between limited irradiation and plant type on plant height at 7 DAP of microgreens *Brassica* sp. The t_6 treatment (lighting 30%) resulted in the highest plant height in broccoli (m_3), reaching 6.55 cm, while the t_4 treatment (lighting 50%) on radish (m_2) yielded a height of 5.89 cm.

Table 2. The Effect of Interaction Between Microgreens Family Brassica Sp. and Limited Irradiation on the Plant Height (7 DAP).

Treatments	m_1 (Cauliflower)	m_2 (Radish)	m_3 (Broccoli)
t_1 (Indoor control)	3,16 c A	2,34 d B	2,41 f B
t_2 (Outdoor control)	2,64 e B	5,06 c A	2,82 e B
t_3 (Lighting 60%)	3,74 b C	5,58 b A	4,86 b B
t_4 (Lighting 50%)	3,49 c C	5,89 a A	4,14 c B
t_5 (Lighting 40%)	3,05 d C	5,52 b A	3,87 e B
t_6 (Lighting 30%)	5,07 a C	5,88 a B	6,55 a A

The variation in plant height is a form of response by plants to the amount of light intensity they receive. When plants are exposed to insufficient light, they undergo etiolation, a process characterized by stem elongation as an adaptive strategy to seek out light sources. This finding is consistent with the study by (Zainal et al., 2022), which reported that white taro plants grown under a shade net at 70% exhibited the most significant height growth. According to (Mukaromah et al., 2019), etiolation occurs when plant growth is limited by insufficient sunlight in terms of both volume and intensity, resulting in abnormal growth characterized by weak, slender, and pale plants. Table 3 shows that both limited irradiation and plant types also had a significant effect on plant height at 4 and 10 DAP.

Table 3. Average of Plant Height 4 DAP and 10 DAP of Microgreens Family *Brassica* sp.

Treatments	Plant Height	
	4 DAP	10 DAP
t_1 (Indoor control)	1,82 b	3,36 c
t_2 (Outdoor control)	2,07 b	4,40 b
t_3 (Lighting 60%)	3,33 a	5,41 a
t_4 (Lighting 50%)	3,97 a	5 a
t_5 (Lighting 40%)	3,74 a	5,28 a
t_6 (Lighting 30%)	3,55 a	5,29 a
CV %	12,57%	6,49%
m_1 (Cauliflower)	2,44 b	4,325 b
m_2 (Radish)	3,84 a	5,531 a
m_3 (Broccoli)	2,96 b	4, 831 b
CV %	22,25%	12,81%
Interaction	No interaction	No interaction

Based on Table 3, the results of the DMRT test at the 5% level indicate that at 4 DAP, treatment t_4 (lighting 50%) independently produced the highest average plant height of 3.97 cm. At 10 DAP, treatment t_3 (lighting 60%) yielded the highest average height of 5.41 cm. The plant type treatment also had a significant effect on plant height at both 4 DAP and 10 DAP. Specifically, the radish treatment (m_2) resulted in the highest average heights of 3.84 cm and 5.53 cm at 4 and 10 DAP. Among the plant types tested, radish produced the highest average height, while cauliflower yielded the lowest. Radish plants were able to grow optimally by meeting their light requirements, thereby maximizing the rate of photosynthesis. According to (Slameto, 2023), light intensity affects the growth and yield of leafy vegetables such as mustard greens, including plant height.

Leaf Areas

The results of the DMRT test at the 5% level, as shown in the Table, indicate that there was no interaction in limited irradiation; however, limited irradiation had a significant effect on leaf area in microgreens of Family *Brassica* sp.

Based on the results of the DMRT test at the 5% significance level (Table 4), both limited irradiation and plant type had a significant effect on the leaf area of microgreen plants from the *Brassica sp*. family. The highest average leaf area was observed in treatment t_2 (outdoor control), with a value of 1.25 cm^2, which was significantly different from the other treatments. This may be since leaf area is strongly influenced by the amount of light intensity received by the plant. The less light intensity received by plants results in a smaller rate of photosynthesis. This is in line with (Wu et al., 2017), who stated that under low light intensity (within the shade net), plants tend to show reductions in both leaf area and leaf thickness. Hakim et al. (2019) reported that low light intensity can inhibit plant growth, leading to smaller leaf areas, similarly to their findings (Hakim et al., 2019).

A decrease in the number of leaves formed also reduces the total leaf area, as the rate of photosynthesis decreases.

Table 4. Average of Leaf Area of Microgreens Family *Brassica* sp.

Treatments	Leaf Area
t_1 (Indoor control)	0,61b
t_2 (Outdoor control)	1,25a
t_3 (Lighting 60%)	0,73b
t_4 (Lighting 50%)	0,57b
t_5 (Lighting 40%)	0,68b
t_6 (Lighting 30%)	0,48b
CV %	20,15%
m_1 (Cauliflower)	0,624b
m_2 (Radish)	0,875a
m_3 (Broccoli)	0,658b
CV %	17,03%

In terms of plant type, the highest average leaf area was observed in m² (radish), with a value of 0.875 cm², which was significantly different from the other plant types. This is likely because each species has distinct morphological characteristics, and radish plants tend to have larger leaf areas compared to broccoli and cauliflower. This finding is supported by Gardner et al. (1991), as cited in (Ardila et al., 2021), who explained that leaf area is influenced by the genetic factors of the plant, including the size and number of leaves.

Table 5. Average of Fresh Weight of Microgreens Family *Brassica* sp.

Treatments	**Fresh Weight**
t_1 (Indoor control)	1,56a
t_2 (Outdoor control)	3,18a
t_3 (Lighting 60%)	2,55a
t_4 (Lighting 50%)	2,58a
t_5 (Lighting 40%)	2,6a
t_6 (Lighting 30%)	2,34a
CV %	13,31%
m_1 (Cauliflower)	3,85b
m_2 (Radish)	6,56a
m_3 (Broccoli)	1,14b
CV %	21,22%

Fresh Weight

Based on the results of the DMRT test at the 5% significance level (Table 5), neither limited irradiation nor plant type had a significant effect on the fresh weight of microgreen plants from the Brassicaceae Sp. Family. In the limited irradiation treatment, the highest average fresh weight was observed in t_2 (outdoor control), with a value of 3.18 grams. However, it was not significantly different from the other light treatments. This outcome is likely influenced by factors such as average leaf area and plant height, which contribute to the fresh weight of the plants. This is consistent with the findings of (Pramitasari et al., 2016) who stated that the greater the plant height and leaf area, the higher the fresh weight of the plant tends to be.

Meanwhile, in the plant type treatment, the highest fresh weight was recorded in the m_2 (radish), with a value of 6.56 grams, although it was not significantly different from the other plant types. This result is likely influenced by plant height and leaf area. This finding aligns with Pramitasari et al. (2016), who stated that fresh plant weight is influenced by plant height and leaf area, where greater height and larger leaves tend to result in higher fresh weight.

Dry Weight

The results of the DMRT test at the 5% level, as shown in Table 6, indicate that there was no interaction in limited irradiation; however, limited irradiation had a significant effect on the dry weight of microgreens from the Brassica sp. family.

Table 6. *Average of Dry Weight of Microgreens Family* Brassica *sp.*

Treatments	Dry Weight
t_1 (Indoor control)	0,6b
t_2 (Outdoor control)	0,77a
t_3 (Lighting 60%)	0,67b
t_4 (Lighting 50%)	0,65b
t_5 (Lighting 40%)	0,61b
t_6 (Lighting 30%)	0,58b
CV %	10,88%
m_1 (Cauliflower)	0,46b
m_2 (Radish)	1,03a
m_3 (Broccoli)	0,45b
CV %	12,87%

Based on the results of the 5% DMRT follow-up test (Table 6), both limited irradiation and plant type had a significant effect on the dry weight of microgreen plants from the family Brassica sp. In the limited irradiation treatment, the highest average dry weight was obtained in t_2 (outdoor control), with a value of 0.77 grams, which was significantly different from the other light treatments. This is likely due to the optimal light intensity received, which supports optimal photosynthesis. In addition, higher dry weight may also be influenced by the greater fresh weight of the plants. This is consistent with the findings of (Sirait & Karyawati, 2019), which reported that under the shade net, plant dry weight tends to decrease because insufficient light availability impairs the photosynthesis process, thereby reducing the accumulation of dry matter in plant organs.

Meanwhile, in the plant type treatment, the highest dry weight was recorded in m_2 (radish), with a value of 1.03 grams, which was significantly different from the other plant types. This result is influenced by the fresh weight and the amount of energy produced during the photosynthesis process. According to (Demetrius et al., 2020), dry weight is the accumulation of organic compounds resulting from the synthesis of substances such as water and carbohydrates, which are highly dependent on the plant's photosynthetic rate.

CONCLUSION

Based on the study's results, an interaction was observed between limited light exposure and the type of *Brassica sp*. microgreens on the parameters of germination uniformity and plant height at 7 days after planting (DAP). The treatment using a lighting 50% (t_4) resulted in the highest germination uniformity for broccoli (m_3), reaching 88%. Furthermore, for the plant height parameter at 7 DAP, the lighting 30% (t_6) treatment also yielded the most significant plant height for broccoli (m_3), which reached 6.545 cm. Meanwhile, exposure to sunlight (outdoor control) yielded the best outcomes in terms of fresh weight and dry weight for radish microgreens.

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