AGROMIX, Volume 16 Number 1 (2025), Pages 109–116

AGROMIX
pISSN (Print): 2085-241X; eISSN (Online): 2599-3003
Website: https://jurnal.yudharta.ac.id/v2/index.php/agromix

Growth and yield response of three lettuce varieties (*Lactuca sativa* L.) with different lighting durations in hydroponic cultivation

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Original article

Article history
Received : February 7, 2025
Accepted : March 10, 2025
Published : March 31, 2025

Keyword:
Hydroponic system;
Irradiation time;
Lactuca sativa L.;
Lettuce varieties;
Morphology;

ABSTRACT

Introduction: Lettuce (*Lactuca sativa* L.) is a popular vegetable plant in Indonesia. This is because the demand for lettuce continues to increase and lettuce plants can be planted with a hydroponic system that is currently in great demand by the community, especially Generation Z (Gen Z). In meeting the demand for lettuce, lettuce is planted hydroponically. Planting in a hydroponic system often does not pay attention to the intensity of light that can be received by plants due to the shade from the GreenHouse or UV plastic used, so plants cannot grow optimally. The purpose of this study was to find the most suitable lettuce varieties planted hydroponically at various irradiation times as well as the most appropriate long light for lettuce plant growth and to analyze the relationship between characters with the yield for indirect selection. **Methods:** The study was conducted at the GreenHouse Arsy Hydroponic using a Completely Randomized Design (CRD) factorial pattern. 3 lettuce varieties and 4 long light treatments were the treatments in this study. The relationship between characters was analyzed using correlation analysis. **Results:** The results of the study showed that the Cos and Batavia varieties can generally be used for planting with a light duration of more than 12 hours compared to the Oakleaf variety. Light duration of less than 12 hours is not recommended because it will cause the plant height to be higher, especially for the Oakleaf variety. In the indirect selection process to obtain high-yielding varieties in the hydroponic system by providing light duration varieties can be selected from the characteristics of the number of leaves, leaf width, and root length which have a significant positive correlation. **Conclusion:** The results of the study showed that selecting the appropriate variety can increase optimal crop yields. Information on the relationship between plant characteristics is very important to increase the effectiveness of selection.

Cite this article:
Wijaya, A. A., Sukmasari, M. D., Nugraha, D. R., Harti, A. O. R., Tifani, A. A., Sukma, R. B., & Andayani, S. A. (2025). Growth and yield response of three lettuce varieties (*Lactuca sativa* L.) with different lighting durations in hydroponic cultivation. *AGROMIX, 16*(1), 109-116. https://doi.org/10.35891/agx.v16i1.6045

INTRODUCTION

Lettuce (Lactuca sativa L.) is a type of lettuce plant that is currently popular among Indonesian people. This is because lettuce has complete nutritional content and various benefits. According to Lal *et al.*, (2024) stated that lettuce contains various nutritional values that are beneficial for humans including vitamins A, K, and C and folate, potassium, fat, protein, flavonoids, beta carotene, phosphorus, iron, carotenoids, and polyphenols. These various nutritional contents make lettuce very beneficial for human health including as a food ingredient for those who are on a diet, an antidote to free radicals that can cause cancer, anti-implantatory, anti-allergic, beneficial in bone formation (Lal *et al.*, 2024), the phytonutrient content contained in lettuce is beneficial in preventing cancer (Bunning & Kendall, 2007). Various nutritional contents and various benefits make the demand for lettuce continue to increase every year.

The highest demand for lettuce is used as a raw vegetable and side dish such as in ready-to-eat food. To meet these needs, conventional lettuce cultivation is constrained by limited land and pests and diseases that attack the plant. One alternative that can be done to increase lettuce production and lettuce quality can be done by planting lettuce hydroponically.

The hydroponic cultivation system is currently being favored by the Indonesian people, especially the younger generation. The concept of agriculture that does not use soil as a growing medium for plants is considered cleaner and an alternative to overcome land limitations due to the increasing population (Chawla, 2023). The hydroponic planting

system is a method of planting plants without soil media by dissolving the nutrients needed by plants through water so that plants can grow optimally (Dubey & Nain, 2020). The hydroponic plant cultivation system is believed to be cleaner and the environment can be controlled more, especially rainfall, because this cultivation is usually carried out in a greenhouse. The results of research by Paes *et al.*, (2023) reported that hydroponic planting is more efficient in harvesting, and vegetables grown hydroponically have a better appearance.

Like conventional cultivation systems, hydroponic cultivation systems can be carried out in various environmental conditions, from lowlands to highlands. Not all lettuce cultivars can grow well in all of these areas, even when cultivated hydroponically. This is related to the adaptability of the lettuce plant. The results of the study by Nguyen *et al.* (2022) reported that planting different lettuce cultivars in a hydroponic system showed different performances. Paes *et al.* (2023) reported that the Lucky Brown cultivar showed better performance than the other two cultivars in both conventional and hydroponic planting. The results of the study by Ekoungoulou & Mikouendanandi, (2020) reported that the Minetto cultivar showed the best yield performance compared to the Blonde de Paris cultivar. Based on the results of these studies, it can be seen that the adaptability of each cultivar to the growing environment is different so the performance of each cultivar, especially the harvest, is very different.

The development of hydroponic lettuce cultivation in lowlands, middlelands, and highlands makes the appearance of lettuce plants different. This is due to differences in the intensity of sunlight received by lettuce plants. Sunlight is used by lettuce for photosynthesis, as well as other growth. Pan & Guo, (2016) stated that for optimal production, plants need optimal light intensity for photosynthesis, affecting plant morphology, and secondary metabolite production. Nguyen *et al.* (2019) reported that in spinach plants, the light intensity received was 190 µmol/m^2/s showed the best net assimilation value and average growth compared to higher or lower light intensities.

The reception of sunlight in the hydroponic system by plants will be different if planted in an open field. This is because the sunlight that enters before being received by the plants will be blocked by the UV plastic used as the GreenHouse roof in hydroponic planting. This will cause the appearance of the plants to be different between hydroponic planting and in the field. The difference in response can be seen in the morphology, flowering process, and fruit formation. The results of the study by Yang *et al.*, (2024) reported that the light conditions received by plants will affect photosynthesis activity, leaf surface expansion, root development, and increased plant biomass. Gavhane *et al.*, (2023) reported that the duration of irradiation in the hydroponic system affects the wet weight, dry weight, and leaf area of lettuce plants.

Research on the intensity of light in a GreenHouse can be done by providing lighting. The length of the lighting time can be adjusted by the length of the lamp lighting. The results of the study by Yan *et al.* (2019) showed that the lighting time of 16 hours per day showed the best effect compared to 14 hours of lighting per day on lettuce plants. The results of the same study were reported by Zhang *et al.*, (2018) who reported that 16 hours of lighting per day combined with a light intensity of 250 µmol/m^2/s gave the best results on lettuce plants. Yudina *et al.*, (2023) reported that providing light for 24 hours increased the total biomass character, and dry weight and increased the photosynthesis process.

The interaction between the use of cultivars between the use of various Lettuce cultivars on the duration of light intensity has not been widely studied. Research on the interaction between the use of cultivars on the duration of light exposure on other plants shows that each cultivar responds differently to the different treatments. This is due to the genetic response of each cultivar. The results of Soufia *et al.*, (2024) reported that lettuce cultivars showed different responses to the provision of different types of light from LED light sources. Emmanuel & Mary, (2014) reported that the local Ofada rice line showed the best performance in plant height characters, 1000 grain weight, and yield potential with higher light intensity increases. Susanti *et al.*, (2023) reported that the sweet corn genotypes tested gave different responses to the provision of light intensity, yield characters showed the best performance under high lighting conditions.

Plant appearance is influenced by three factors, namely genetic factors, environmental factors, and the interaction of genetic and environmental factors. These three factors will affect the overall appearance of the plant. Wijaya *et al.* (2022) reported that genetic interactions with the environment caused the appearance of soybeans planted in three environments to show inconsistent appearance. This is a phenomenon that will occur in testing a cultivar planted in various environmental growing conditions. In the hydroponic cultivation system, lettuce plants that are given long exposure treatment will cause the ability of each cultivar to vary. This will be an interaction between the two treatments. Lettuce cultivars that can adapt to full light or low light conditions will show a consistent appearance. The purpose of this study was to analyze the interaction between lettuce cultivars and the provision of long exposure to light in hydroponic cultivation systems. The results of this study are expected to be applied to hydroponic lettuce cultivation in various areas.

METHODS

Location and time of research

This research was conducted in the Asry Hidroponik office room located at Jalan Suma gang Kramat No. 54, Majalengka Kulon Village, Majalengka District, Majalengka Regency with an altitude of 121 meters above sea level. This research was conducted in March 2023. The cultivars tested in this study were the Oakleaf Lavina variety, the Cos Maximus variety, and the Batavia SV 662 variety (Description in Table 1).

Table 1. Description of three lettuce varieties

No	Character	Oakleaf Lavina	Cos Maximum	Batavia SV 662
1.	Maturity	30-40 HST	45-50 HST	45-55 HST
2.	Size of the tuber	Medium rather large	Currently	Currently
3.	Color of the stump	Light green	Light green	Light green
4.	The density of the tuber	Loose	Congested	Congested
5.	Leaf surface	Good	Good	Good
6.	Superiority	The lettuce has a good physical appearance light green leaves, and fast growth.	Adaptive to hot conditions	Resistant to yellow powdery mildew infection, easy to harvest, light green leaf color, and longer shelf life

Research design

This research was conducted indoors with a split-plot design. Repeated three (3) times. Details of the treatments tested can be explained as follows:

The first factor is the type of cultivar (K) which consists of 3 levels, namely:

k_1 = Oakleaf Lavina cultivar
k_2 = cultivar Cos Maximus
k_3 = cultivar Batavia SV 662

The second factor is the duration of exposure (P) which consists of 4 levels, namely:

p_1 = 6 hours
p_2 = 12 hours
p_3 = 18 hours
p_4 = 24 hours

Data analysis

Field observation data were analyzed using the Complete Random Design (CRD) method with a factorial pattern. To determine the differences between treatments, Duncan's multiple range test was used at the 95% level (Ramachandran & Tsokos, 2000). Correlation analysis is used to see the relationship between observed variables and the yield of hydroponically cultivated lettuce (Senthilnathan, 2019). Data analysis was carried out with the help of SPSS software version 25.

The variables observed in this study were plant height (cm), number of leaves, leaf width, root length (cm), and economic weight (g). In addition to the main variables, the supporting variables observed are water pH, ppm, indoor air humidity, and indoor air temperature.

RESULTS AND DISCUSSION

Supporting environmental conditions during the experiment

In addition to the treatments tested, other factors during the experiment can affect plant growth and yield. Other factors that affect the growth and yield of lettuce plants in this experiment are the pH of the water during the experiment, ppm, indoor air humidity, and indoor air temperature during the experiment.

Based on the results of observations during the experiment, the pH of the water in the hydroponic installation ranged from an average of 6.3. The minimum pH was 5.3 and the maximum pH was 7.8. The pH of hydroponic water greatly affects the growth and yield of lettuce plants. The pH condition will affect the process of availability of nutrients needed by plants so that the absorption of nutrients will be disrupted. The results of the study by Gillespie *et al.* (2020) reported that there was a decrease in the content of phosphorus, calcium, magnesium, sulfur, boron, manganese, and zinc in the leaves, while the potassium and aluminum content increased when the pH value

decreased. The results of the study by Kudirka *et al.* (2023) reported that differences in pH would be reflected in the physiological response of plants.

Based on the results of the nutrient solution observations, the average ppm value was 1739.6 with a minimum ppm of 1284 and a maximum ppm of 2657. At the beginning of planting, the use of nutrients was around 1200 ppm, but in the third week, the ppm value increased because some nutrients settled and also caused damage to the tips of lettuce leaves such as burning (tip burn). This is by the research results of Efendi & Murdono, (2021) that low pH values and high EC values can cause damage to the tips of the leaves. The higher the PPM value, the more concentrated the nutrient solution is so that the availability of nutrients increases, according to Brechner & Both, (2013) ppm used for lettuce plants ranges from 560-840 ppm. If the ppm is too high, the plant is no longer able to absorb nutrients because it is saturated, the saturation limit for leafy vegetables is EC 4 or 28000 ppm, above EC 4 plant growth will stagnate, if the EC is higher, toxicity or poisoning will occur and cells will experience plasmolysis (Mitchel *et al.*, 2023).

Based on the observation results, the average daily temperature in the research room was 28.2 ^{o} C with a minimum temperature of 25.8 ^{o} C and a maximum temperature of 30.7 ^{o} C. Temperature can affect the metabolic processes of plants, one of which is the process of photosynthesis. Photosynthesis can take place optimally if the environmental temperature is optimal (Karmila & Andriani, 2019). According to Brechner & Both, (2013), The suitable temperature for lettuce cultivation is 15-25 ^{o} C, temperatures above 30 ^{o} C can inhibit growth, and stimulate the growth of flower stalks (*Bolting*). The productivity of a plant will decrease if the plant is placed in climate conditions that are not optimal for a plant (Karmila & Andriani, 2019) in high temperatures, chemical reactions run faster so that the physiological processes of the plant will be disrupted, in addition to disrupting plant growth and development, temperatures that are too high cause lettuce to taste bitter (Zhang *et al.*, 2024). The results of the study (Crous et al ., (2022) increased environmental temperature causes plant respiration to increase.

Based on the observation results, the average humidity in the research room was 65.9% with a minimum humidity of 47% and a maximum humidity of 83%. Humidity that is too high will cause evapotranspiration to run slowly, and the absorption capacity of plant roots to obtain nutrients and nutrients is reduced. While humidity that is too low will cause evapotranspiration to be faster and not balanced with the availability of water by the roots so plants are more easily wilted or stressed. According to Brechner & Both, (2013), Too much humidity will trigger the development of pathogenic fungi.

Morphological appearance of lettuce varieties at various light exposure times

The results of statistical analysis showed that interaction occurred between variety type and duration of irradiation on plant height (Table 2) and root length (Table 3).

Table 2. The effect of interaction between varieties and duration of light exposure on plant height (cm) of lettuce plants.

Treatment	p_1 (6 hours)	p_2 (8 hours)	p_3 (12 hours)	p_4 (24 hours)
v_1 (Oakleaf Variety)	51.17^{b}	51.67^{b}	43.17^{b}	41.17^{b}
	B	B	A	A
v_2 (Cos Variety)	19.33^{a}	15.87^{a}	19.13^{a}	19.93^{a}
	AB	A	AB	B
v_3 (Batavia Variety	19.90^{a}	18.03^{a}	19.70^{a}	19.63^{a}
	A	A	A	A

Description: The average value followed by the same letter in the same column (lower case letters) and the same letter in the same row (capital letters) shows no significant difference based on the Duncan test at 95% level.

Table 2 shows that the interaction between the Oakleaf variety and the duration of light exposure has a higher effect on plant height compared to the interaction between the Cos variety and the duration of light exposure and the interaction between the Batavia variety and the duration of light exposure. The interaction of the Oakleaf variety with a duration of light exposure of 8 hours showed a higher plant height. This is thought to be due to the low light received by the Oakleaf lettuce plant, coupled with the characteristics of the Oakleaf variety which has dense tubers and long leaves, so that the plant height becomes high. The light received by the plant will activate the auxin hormone to continue to be produced. If the light received is low, the auxin hormone will be produced in excess, which will accelerate the cell elongation process. The research results of Yun *et al.*, (2023) reported that the auxin hormone can interact with the photoreceptors PHY, PHOT, and CRY to regulate root growth and development. The results of other studies show that lighting greatly affects the vegetative process of plants, especially plant height and leaf area (Miao *et al.*, 2023; Kang *et al* ., 2013; Sumarlan *et al.*, 2023).

Table 3 shows that there is an interaction between the use of lettuce varieties and the duration of irradiation on the root length character. The results of the analysis can be seen as follows:

Table 3. Effect of interaction between variety and duration of irradiation on root length (cm)

Treatment	p1 (6 hours)	p2 (8 hours)	p3 (12 hours)	p4 (24 hours)
v1 (Oakleaf Variety)	43.57[a]	15.87[a]	27.77[a]	28.10[a]
	A	AB	B	B
v2 (Cos Variety)	35.77[a]	18.03[a]	51.53[b]	52.80[b]
	A	B	C	C
v3 (Batavia Variety)	26.13[a]	51.67[b]	43.70[b]	50.77[b]
	A	B	BC	C

Description: The average value followed by the same letter in the same column (lower case letters) and the same letter in the same row (capital letters) shows no significant difference based on the Duncan test at 95% level.

The interaction between the Cos variety and the 24-hour light exposure showed the longest root length (52.80 cm) (Table 3). Table 3 also shows that longer light exposure causes the root length to be relatively longer in each variety compared to shorter light exposure. This is thought to be due to the very active vegetative growth process of plants in low light exposure conditions. The energy required by plants is higher for vegetative growth (plant height and leaf area) in low-light conditions, which will interfere with root growth. The results of Zheng *et al.* (2019) reported that a 16-hour light exposure showed the maximum root length in hydroponically grown strawberry plants. Kurata & Yamamoto, (1997) reported that increasing the photosynthesis process would stimulate root growth. Gendron & Staiger, (2023) stated that the length of light exposure and the type of plant affect hormone regulation in the plant. Lettuce is a long-day plant, with increasing lighting duration will cause photosynthate accumulation to be longer which will affect the vegetative growth of the plant. Low irradiation will disrupt the process of auxin distribution through the phloem and reduce gene regulation which can inhibit plant root development (Korobova *et al.*, 2023).

The results of statistical analysis showed that there was no interaction effect between the use of varieties and the duration of irradiation on the number of leaves, leaf width and economic weight per plant (Table 4). The results of the analysis of the independent influence of each treatment can be seen in Table 4.

Table 4. Independent effect of variety use and duration of lighting on number of leaves (Sheets), Leaf width (cm), and economic weight per plant (g)

Treatment	Number of Leaves (Shells)	Leaf Width (cm)	Economic Weight per Plant (g)
Cultivar (K)			
v_1 (Oakleaf)	26.70 ± 1.5[b]	14.62 ± 0.4[b]	51.98 ± 5.7[a]
v_2 (Cos Maximus)	15.78 ± 1.5[a]	11.22 ± 0.4[a]	70.28 ± 5.7[a]
v_3 (Batavia)	15.94 ± 1.5[a]	11.08 ± 0.4[a]	52.05 ± 5.7[a]
Exposure Time (P)			
p_1 (6 hours)	13.41 ± 1.7[a]	5.36 ± 0.5[a]	8.18 ± 6.6[a]
p_2 (12 hours)	18.40 ± 1.7[ab]	11.06 ± 0.5[b]	38.04 ± 6.6[b]
p_3 (18 hours)	24.71 ± 1.7[c]	15.37 ± 0.5[c]	77.37 ± 6.6[c]
p_4 (24 hours)	21.35 ± 1.7[bc]	17.46 ± 0.5[d]	108.81 ± 6.6[d]

Description: The average value followed by the same letter (Superscript) in the same column shows no significant difference based on the Duncan test at 95% level.

Table 4 shows that the Oakleaf variety shows the best number and width of leaves compared to other varieties. While in economic weight all varieties show the same appearance. This is thought to be related to the genetic nature of the plant itself. Wijaya *et al.* (2022) stated that the genetic characteristics of plants greatly affect the appearance of a plant grown in certain environmental conditions. Based on the plant description (table 1), the Oakleaf lettuce variety has larger leaves than other varieties, only the Cos maximus and Batavia varieties have better leaf density than the Oakleaf variety so the economic weight of the three varieties is not different.

The independent effect of the duration of light exposure shows that the duration of light exposure of more than 12 hours shows a good effect on the character of the number of leaves, leaf width, and economic weight of lettuce plants. This is thought to be because lettuce plants are included in long-day plants. Widodo *et al.*(2022) stated that the longer the lettuce plants receive light, the better the plant growth will be. The results of Wu *et al.* (2024) reported that photoperiodicity is closely related to the photosynthesis process of plants, long light exposure will increase the photosynthesis process, and metabolism in tomato plants.

Relationship between lettuce characters and yield

Information on the relationship between growth traits and yield is essential for direct and indirect selection to obtain varieties that are adaptive to certain environmental conditions. The results of the analysis of the relationship between lettuce variety traits planted at various light exposure times can be seen in Table 5.

Table 5. Relationship between lettuce varieties characters at various lighting times

	TT	*JD*	*LB*	*PA*	*BE*
TT	1				
JD	0.455473	1			
LB	0.194491	**0.911392**	1		
PA	**-0.53734**	0.197876	0.464472	1	
BE	-0.16894	**0.649801**	**0.798761**	**0.76613**	1

Description: TT = Plant height (cm); JD = Number of leaves (strands); LB = Leaf width (cm); PA = Root length (cm); and BE = Economic weight per plant (g); values in bold indicate a significant correlation based on the 95% level.

Based on the correlation table (Table 5), it can be seen that there is a significant negative and significant positive relationship. Characters that have significant negatives are plant height and root length. This means that the provision of lighting duration and lettuce varieties will show the opposite relationship. If the plant height increases, the root length will decrease and vice versa. This is thought to be due to the length of lighting affecting the formation of plant hormones. While the correlation between plant height and economic weight shows a negative but not significant relationship.

The correlation relationship that shows significant positive with the results (economic weight) is the character of the number of leaves, leaf width, and root length. Increasing the number of leaves, leaf width, and root length will increase the economic weight of the plant. To get high results, selection can be made based on these characters. Wu *et al.*(2024) explained that the duration of irradiation will affect the photosynthesis process, plant metabolism, and the nutrient content contained in the plant, which will indirectly affect the weight of a plant. In addition, plant genetics greatly affect the appearance of plant characters.

CONCLUSION

Research between the use of plant varieties and the duration of lighting is very useful for optimizing the production of lettuce plants grown hydroponically. These results are useful in the development of hydroponics in lowlands which generally have longer lighting times than middle or highlands. Cos and Batavia varieties can generally be used for planting with more than 12 hours of light exposure compared to Oakleaf varieties. Light exposure of less than 12 hours is not recommended because it will cause higher plant heights, especially in Oakleaf varieties. In the indirect selection process to obtain high-yielding varieties in hydroponic systems by providing light exposure varieties can be selected from the characters of the number of leaves, leaf width, and root length which have a significant positive correlation.

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