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Growth and Yield of Vertical Hydroponic Lettuce under Liquid Organic Fertilizer and Shade Intensity Treatments

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ABSTRACT

Lettuce (Lactuca sativa L.) production needs to be increased to fulfill increasing demand. Application of liquid organic fertilizer (LOF) in the hydroponic nutrient solution and adding shade to reduce solar radiation intensity are expected to improve lettuce yield. The purpose of this study was to investigate the effect of providing shade and adding LOF as a nutrient to optimize the results of hydroponic lettuce cultivation in Situbondo Regency. This study used a factorial Randomized Block Design (RBD) with UV plastic shading as a factor at different levels, namely 6% and 14%. The second factor was the nutrient composition used, namely 100% AB mix, 25% LOF + 75% AB mix, and 50% LOF + 50% AB mix. The results showed that the interaction of the two factors showed a significant difference in the chlorophyll content of plant leaves. The application of each factor was able to influence plant height, number of leaves, fresh weight, leaf area, leaf color, and crispness level, but did not affect the canopy area of lettuce plants. The use of 14% UV plastic and the addition of 25 LOF, separately resulted the highest yield of lettuce.

1. INTRODUCTION

Lettuce are green vegetables that contain many nutrients such as protein, carbohydrates, fiber, fat, calcium, phosphorus, iron, vitamins (A, B1, B2, B3, C) and water (Ariananda *et al*., 2020). The demand for lettuce has increased over time as Indonesians have become more aware of healthy eating habits and nutritional needs. This increase in demand can be seen in the rise in vegetable consumption among Indonesians, which has reached 97.29% (Dewi *et al*., 2023). However, lettuce production in Indonesia is quite volatile due to climatic factors and the increasing scarcity of agricultural land.

Hydroponics is an alternative solution to increasingly limited agricultural land, as its cultivation technique mechanically uses media other than soil, namely water and nutrient solutions (Fevria *et al*., 2023). One type of hydroponics that is suitable for application in the current situation is vertical hydroponics (verticulture). Verticulture is a hydroponic cultivation technique that is arranged in tiers and faces upwards (vertically). The advantages of the vertical hydroponic system (verticulture) are that it saves land, is easy to move, has a larger capacity, and is artistic (Suryandari *et al*., 2024).

Hydroponic cultivation efforts also encounter several obstacles, such as high solar radiation, which can cause plants to dry out, and the high cost of purchasing nutrients. Therefore, an alternative that can be implemented is the use of UV plastic shade to reduce excessive solar radiation intensity, which can cause an increase in temperature and inhibit the rate of plant respiration (Hidayat *et al*., 2022). A solution to minimize cultivation costs is the addition of liquid organic fertilizer (LOF). LOF based on the fermentation of organic materials can be obtained at a more affordable price (Putra *et al*., 2021). The use of liquid organic fertilizer can help improve lettuce growth, while also considering nutrient

availability and environmental conditions (Endoh.T *et al*., 2024). Based on research by Bachtiar *et al*. (2021), adding LOF as a hydroponic nutrient has a significant effect on the growth and production of hydroponic lettuce plants.

According to Hutagalung *et al*. (2021), differences in solar radiation intensity have a significant effect on the growth and production of lettuce plants. The optimal radiation intensity recommended for hydroponic lettuce growth (180–250 µmol m^{-2} s^{-1} atau 44–70 W m^{-2}) as reported by Wang *et al*. (2023) and Dai *et al*. (2023). The application of 6% and 14% UV plastic shade is expected to reduce radiation to near the optimum level for photosynthesis and increase plant growth efficiency. Therefore, the objective of this study is to analyze the combination of liquid organic fertilizer application and differences in radiation intensity on lettuce production in vertical hydroponics.

2. RESEACH METHOD

Research was conducted at the Green House located in Adirejo Village, Situbondo District, Situbondo Regency, with geographical coordinates 7°42'S 113°58'E. Research was conducted from October to December 2024. The study used a Factorial Randomized Block Design (RAK). This experimental design involved two main factors. The first factor was the difference in radiation intensity, consisting of N1 (6% UV plastic shading) and N2 (14% UV plastic shading). The second factor was the concentration of LOF as hydroponic plant nutrients, consisting of P0 (Control, only AB mix), P1 (25% LOF + 75% AB mix), and P2 (50% LOF + 50% AB mix). There were six treatment combinations with four replicates, resulting in 24 experimental units. Each unit consisted of 10 planting holes. The plan for the combination of experiments was presented in Table 1.

Table 1. Lay out for lettuce planting using vertical hydroponic under LOF and UV plastic shading treatments

Shading N1 (6% UV Plastic)				Shading N1 (14% UV Plastic)			
P1U2	P1U1	P1U3	P1U4	P2U3	P2U1	P2U4	P2U2
P0U2	P0U3	P0U4	P0U1	P1U4	P1U2	P1U3	P1U1
P2U1	P2U4	P2U3	P2U2	P0U3	P0U1	P0U4	P0U2

2.1. Materials and Tools

The equipment used during the study included net pots, measuring cups, TDS meters, pH meters, RH meters, thermometers, 6% and 14% UV plastic, tent stands, 20-W AC water pumps, 4-inch PVC pipes, ¾-inch PVC pipes, rock wool, and flannel cloth. The materials used included lettuce seeds, water, AB mix nutrients, planting media, electricity, liquid organic fertilizer, and HNO_3.

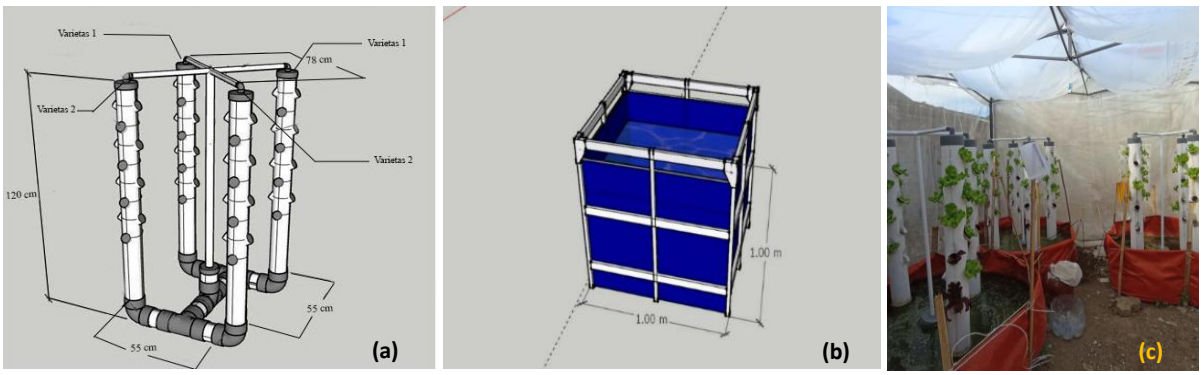

Figure 1. (a) Vertical hydroponic installation; (b) Hydroponic nutrition stock, (c) Vertical hydroponic in work

Vertical hydroponic installation used in this experiment was illustrated schematically in Figure 1. This study utilized a vertical hydroponic system constructed using four primary PVC pipes with a diameter of 4 inches and a height of 120 cm each. Lettuce seedlings were planted at a spacing of 20 cm, resulting in a planting capacity of 20 plants per pipe (Figure 2). The entire hydroponic structure was positioned within a nutrient reservoir. The nutrient solution was

delivered vertically using a pump, allowing it to flow through the four PVC pipes under gravitational force from the top to the bottom. This configuration ensures uniform distribution of nutrients and irrigation across all plants. The pump operated for 8 h during the daytime. The vertical hydroponic system was installed in two separate greenhouses covered with UV plastic films of 6% and 14%, providing shading levels of 6% and 14%, respectively, for the cultivated plants.

2.2. Procedures

The first step is to build a vertical hydroponic installation using 4-inch diameter PVC pipes 120 cm long, assembled with additional hydroponic nutrient tanks in the form of 1m x 1m x 1m sized tarps. Then a greenhouse measuring 3m x 3m x 3m was constructed. Planting preparation starts with sorting high-quality lettuce seeds, then seeding with rockwool that's been moistened with just enough water. Seeding is done until the seeds are 14 days old. Next, prepare the doses of AB mix nutrient stock solution and LOF stock solution before transplanting. After 14 days, the seeds are transplanted to vertical culture installations located in greenhouses with 6% and 14% UV plastics. Greenhouse 6% means that UV plastic can reflect 6% of solar radiation, so that 94% of radiation enters greenhouse I. The second greenhouse is 14%, which means that UV plastic can reflect 14% of solar radiation, so that only 86% of radiation enters greenhouse II.

The maintenance and checking of environmental indicators are carried out every day at 07:00, 13:00, and 17:00 WIB until the harvest age of 45 HSS. The environmental indicators observed include temperature, humidity, and solar radiation intensity. Other maintenance activities include adding water and nutrients every 2 days. Nutrient addition is adjusted according to the specified treatment. Installation one is given a 100% AB mix dose. Installation two is given 25% LOF and 75% AB mix. Installation three is given 50% LOF and 50% AB mix. These treatments are also carried out in the second greenhouse. Each greenhouse contains three installations with different treatments.

2.3. Data Analysis

In addition to observing the environment, observations were also made on the cultivation results. Plant parameter observations include plant height, leaf width, root volume, chlorophyll content, number of leaves, fresh weight, leaf area, canopy area, leaf color, and crispness level. This is done to determine the effect of treatment combinations on lettuce plants. Seven observation variables were identified, two of which were qualitative and five quantitative, to be analyzed using analysis of variance (ANOVA) at a 5% level.

3. RESULTS AND DISUCUSSON

Lettuce cultivation is carried out for 45 days. Cultivation activities are divided into two stages, first in the nursery and then transplanted to the vertical culture installation. The cultivation process after transplanting to the vertical cultivation facility involves several treatments consisting of nutrient concentrations ranging from 600-1000 ppm, which are applied gradually, an average pH of around 7 because the pH of the raw water is quite high at between 8-9, and then lowering the pH by gradually adding HNO_3.

Environmental parameters play a major role in plant growth and development. Air humidity plays a role in controlling growth. The average daily humidity during the planting period ranges from 60-81%, as shown in Figure 2. Humidity levels in the study area are conducive to lettuce growth. Kumsong *et al*. (2023) reported that Roman lettuce

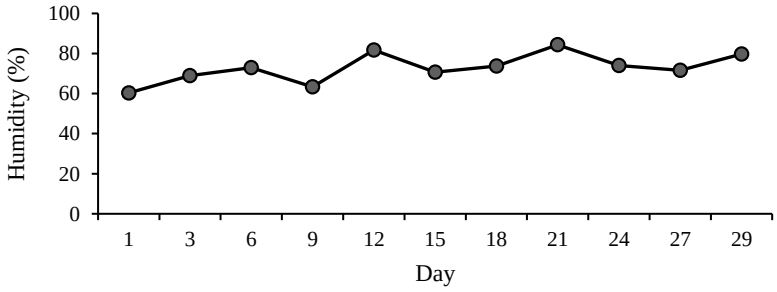

Figure 2. Chart of daily humidity outside the greenhouse

grown in tropical greenhouses with RH in the range of 56-66% (daytime) performed well. Farhangi *et al*. (2023) recommend an RH of 50-60% for lettuce cultivation in vertical farming systems. The treatment of different percentages of UV plastic used will affect several microclimate factors such as temperature and radiation intensity entering the cultivation area. Air temperature and radiation intensity during the planting period are recorded in Figure 3.

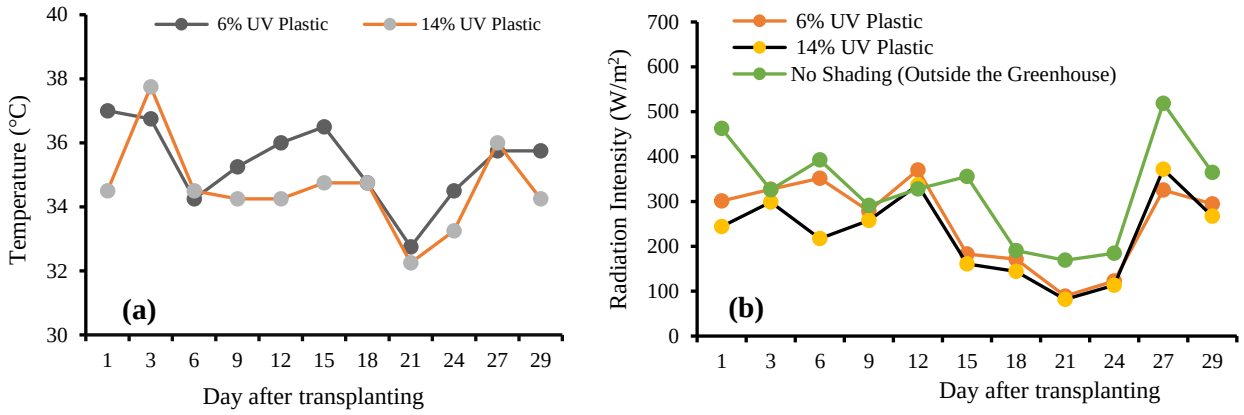

Figure 3. (a) Graph of daily temperature; (b) Graph of daily radiation intensity

Figure 3 (a) shows the results of daily air temperature observations in the 6% greenhouse ranging from 28 – 38.7 ℃, while in the 14% greenhouse the temperature ranged from 27-37 ℃. These conditions are not ideal for lettuce growth. The optimal air temperature for growth in general in a controlled hydroponic/greenhouse system is in the range of 17-24 °C (Miller *et al*., 2020). Temperatures above 25-30 °C begin to enter unfavorable conditions, where plants are potentially experiencing heat stress, accelerated bolting, and a decline in quality (Wang *et al*., 2023). The average radiation intensity value, as shown in Figure 3 (b), outside the greenhouse is around 305.1 W/m². Meanwhile, inside the greenhouse, 6% is 259.1 W/m² and 14% is 238.9 W/m². The radiation intensity is far above the optimal conditions recommended based on the results of Wang *et al*. (2023) research, which is 44–70 W m^{-2}.

Tabel 2. Summary of *F*-calculations for all variables on the effect of radiation intensity and nutrient composition on the growth and yield of lettuce under vertical hydroponic cultivation

Variables	UV Plastic (N)			LOF (P)			Interaction (Nx P)		
	F-count	F-5%	F-1%	F-count	F-5%	F-1%	F-count	F-5%	F-1%
Height of Plants	0.405 ns	4.41	8.29	2.128 ns	3.55	6.01	2.838 ns	3.55	6.01
Widht of Leaves	1.847 ns	4.41	8.29	4.072 *	3.55	6.01	3.054 *	3.55	6.01
Root Volume	529.1 **	4.41	8.29	37.36 **	3.55	6.01	20.36 **	3.55	6.01
Chlorophyll Content	0.01 ns	4.41	8.29	1.92 ns	3.55	6.01	4.98 *	3.55	6.01
Leaf Count	8.37 *	4.41	8.29	6.97 **	3.55	6.01	0.40 ns	3.55	6.01
Weight (gram)	13.31 **	4.41	8.29	5.09 **	3.55	6.01	1.80 ns	3.55	6.01
Leaf Area (cm)	22.36 **	4.41	8.29	9.74 **	3.55	6.01	0.13 ns	3.55	6.01
Canopy Area (cm)	0.88 ns	4.41	8.29	1.41 ns	3.55	6.01	0.30 ns	3.55	6.01

Notes: (ns) not significant; (*) significant; (**) very significant

The effect of treatment on plant parameters was analyzed using analysis of variance (ANOVA) at a 5% level, as shown in Table 2. In general, the level of shade and the composition of liquid organic fertilizer had a significant effect on the physiological performance and productivity of lettuce. The shading treatment had a very significant effect on root volume, fresh weight, and leaf area, and a significant effect on the number of leaves, indicating that reducing radiation intensity through UV plastic was able to create a cooler and more humid microclimate, which supports photosynthetic activity and biomass accumulation. LOF treatment also had a significant to very significant effect on several parameters such as leaf width, root volume, number of leaves, fresh weight, and leaf area, indicating that a combination of organic and inorganic nutrients can improve vegetative growth by increasing the availability of macro and micro nutrients. The

interaction between the two factors showed a significant effect on leaf width, root volume, and chlorophyll content, indicating synergy between radiation intensity and nutrient availability in supporting leaf tissue formation and photosynthetic efficiency.

3.1. Height of Plants

Environmental factors that can affect plant height growth include radiation intensity. The results of the study in Figure 4 show that plant height does not differ significantly between different shades or different LOF combinations. The height of plants in the 14% UV plastic treatment was higher because they received less radiation intensity compared to the 6% greenhouse. High radiation intensity in greenhouses can cause plants to be shorter because cell elongation influenced by the hormone auxin works more actively in darker conditions (Tuo *et al*., 2021).

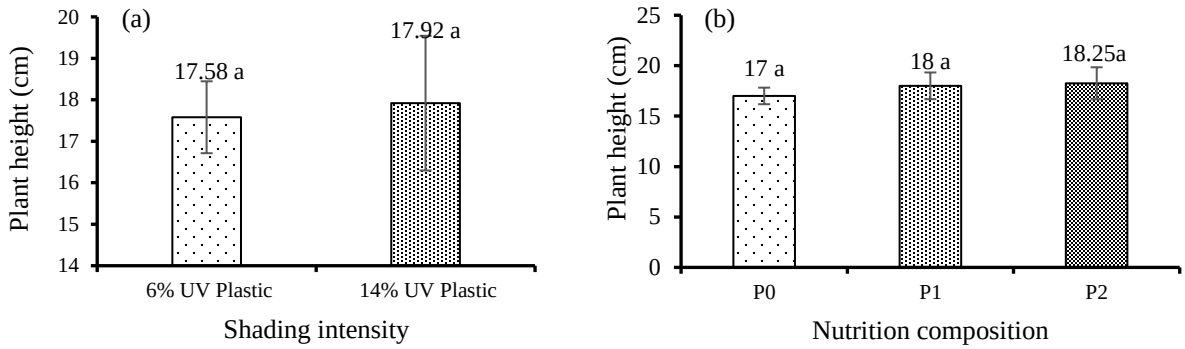

Figure 4. Effect of treatment factors on plant height of lettuce: (a) UV plastic factor, (b) Nutrient composition

The height of plants treated with P2 (50% LOF) was higher than that of other treatments because the combination of AB Mix and LOF nutrients provided to lettuce plants was available in the amounts needed by lettuce plants. The combination of AB Mix and LOF nutrients can increase nutrients so that plant nutrients are fulfilled. The macro and micro nutrients contained in inorganic fertilizers are higher than those in organic fertilizers, but the combination of the two can increase plant growth and reduce harmful residues from the use of chemicals (Tahirah & Koesriharti, 2024).

3.2. Widht of Leaves

The width of the leaves is measured when the lettuce plants have been transplanted until harvest. Measurements are taken once a week using a ruler, starting from the left and right edges of the leaves or vice versa. Leaf width affects plant growth because it contributes to the process of photosynthesis.

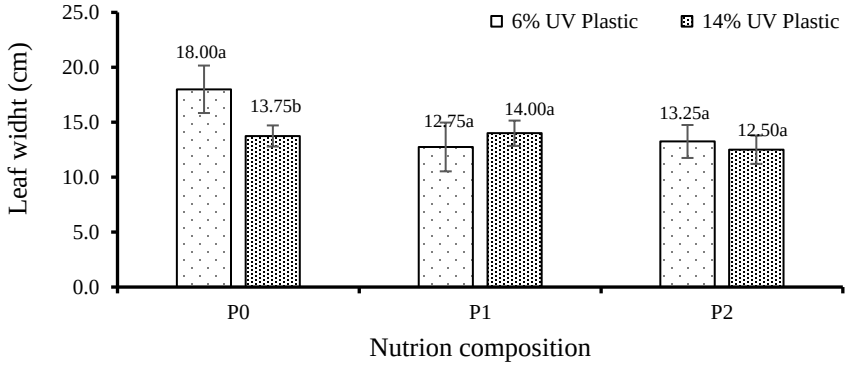

Figure 5. Effect of nutrition composition and shading intensity on the leaf width of lettuce under vertical hydroponic cultivation

The results of the diagram above show that there is an interaction between the level of shade and the combination of nutrients on the width of lettuce leaves. The combination of 14% greenhouse shading and 25% LOF application resulted in the best leaf width compared to other treatments. This is because the combination of AB Mix and LOF provides the appropriate amount of nutrients needed by lettuce plants. The combination of LOF and AB Mix nutrients has a positive effect on plant growth and yield (Yulia & Manja, 2022).

Plants grow optimally when the nutrients in fertilizer are sufficient to assist in the metabolic process of leaf growth. Leaf size affects photosynthesis in plant growth. Excessive solar radiation can cause stress to plants. Leaves under 14% greenhouse shade obtained the highest value because the radiation received by the plants was less than that received by plants under 6% greenhouse shade. The intensity of solar radiation will affect the size of the leaves. Plants that are in conditions of low radiation will adapt by changing their morphological and physiological properties by expanding the leaf surface and increasing chlorophyll.

3.3. Root Volume

Root volume is calculated at harvest time when the lettuce plants are 45 days. Root volume can be calculated by separating the roots from the tops. The roots are cleaned and placed in a glass containing 400 ml of water, and the increase in water volume in the glass is then calculated. Root volume in lettuce plants needs to be considered because root volume affects the ability of the roots to absorb water and nutrients needed by the plant.

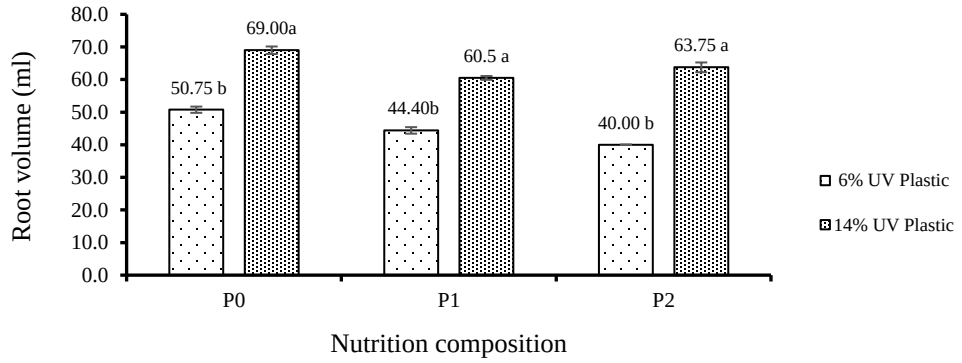

Figure 6. Effect of nutrition composition and shading intensity on the root volume of lettuce under vertical hydroponic cultivation

According to the diagram above, treatment P2 (LOF 50%) produced results that were not significantly different from treatment P0 (control). This is because the combination of AB Mix and LOF nutrients was sufficient for the lettuce plants. Larger root volumes had longer roots. This indicates that a good root system has a greater ability to absorb nutrients (Yulia & Manja, 2022). Sufficient P for plants can form a good root system. Root volume is an important factor in growth because roots are able to absorb the nutrients needed by plants for photosynthesis. The photosynthesis process requires sufficient solar radiation because if full solar radiation exceeds the optimum requirement, it will cause the plants to wilt and photosynthesis to slow down (Adinata & Hariyono, 2023).

3.4. Chlorophyll Content

Data analysis using ANOVA showed a significant difference in the interaction between radiation intensity and nutrient concentration. The addition of LOF can increase the supply of nutrients in the nutrient solution. The nutrient that most influences chlorophyll formation is nitrogen (N). Nitrogen content reflects the chlorophyll content in plants (Firmansyah *et al*., 2021). Organic fertilizer can equalize plant growth in less than optimal conditions. Sufficient nutrients can increase photosynthetic activity. High photosynthetic activity can supply high chlorophyll content. In addition, photosynthesis also involves the role of sufficient solar radiation to process carbon dioxide and water into oxygen and sugar, which will be used as a food source for plants. An optimal photosynthetic process can also support leaf growth and enlarge the stems of lettuce plants (Ambarwati *et al*., 2023).

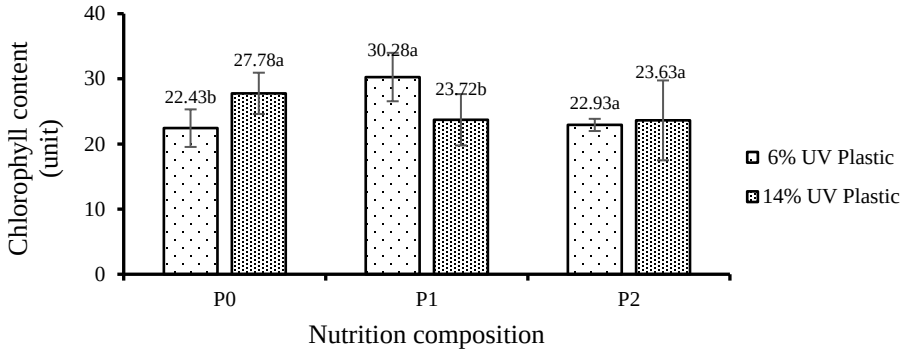

Figure 7. Effect of nutrition composition and shading intensity on the chlorophyll content of lettuce under vertical hydroponic cultivation

3.5. Number of Leaves

Leaf count was conducted during the post-harvest stage when the lettuce plants were 45 days old. Leaf count was performed manually on each sample. Both treatment factors applied were able to influence the leaf count value. Figure 7 shows the results of further statistical tests related to the observation variable number of leaves. According to the diagram above, there was no correlation between the two factors, but the treatment factors were able to influence the number of leaves. A hydroponic plant that suffers from nutrient deficiency will slow down its growth and development (Lutfiah *et al*., 2023). Therefore, the addition of LOF is intended to increase the availability of macro and micro nutrients in hydroponic nutrient solutions. It has been proven that the addition of 25% LOF produces more leaves than other treatments. The effect of radiation intensity also affects the number of leaves, where solar radiation provides energy used for photosynthesis and the formation of new leaves. The measurement results also show that greenhouses with 6% UV plastic are able to produce more leaves than greenhouses with 14% UV plastic. A decrease in solar radiation energy can interfere with plant growth, thereby reducing plant biomass production (Hutugalung *et al*., 2021). This statement mainly refers to the formation of new leaves.

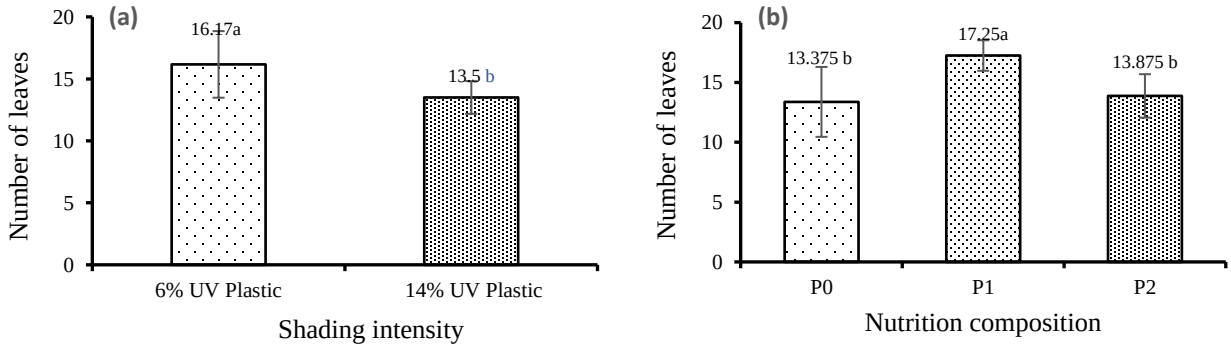

Figure 8. Effect of treatment factors on the number of leaves of lettuce: (a) UV plastic factor, (b) Nutrient composition

3.6. Fresh Harvest Weight

The weight of the plants were measured after harvesting, when the lettuce was 45 days. The parts measured were the stems and leaves. The results of the variance analysis showed that there was no significant difference between the two treatment factors, but each factor was able to influence the fresh weight value. The greenhouse treatment with 6% UV plastic with a dose of 25% LOF + 75% AB mix had the highest average fresh weight value.

The amount of weight is directly proportional to the number of leaves because the leaves of vegetable crops such as lettuce contain high water content, resulting in higher fresh weight of the crop (Hilalliyah *et al*., 2017). A perfect

photosynthesis process will produce an abundant food supply for plants, resulting in the formation of new leaves that can increase the amount of fresh weight. Commercially grown lettuce of the same variety, namely Claribel, has a fresh weight value ranging from 140 - 170 grams, while the results of this study produced a fresh weight ranging from 108 - 152 grams. This weight value is competitive with lettuce commonly found in traditional and modern markets. In general, the high and low fresh weights depend on the plant biomass.

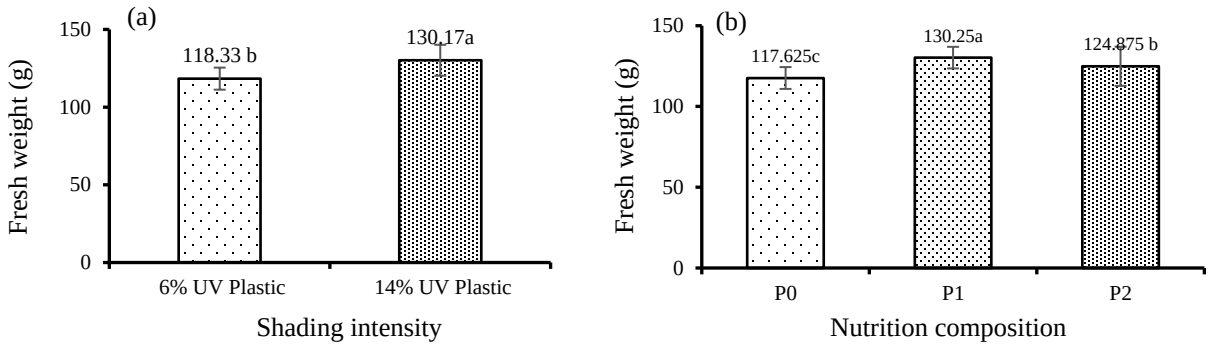

Figure 9. Effect of treatment factors on the fresh harvest weight of lettuce: (a) UV plastic factor, (b) Nutrient composition

3.7. Leaf Area

Leaf area was calculated using ImageJ software. Calculations were performed on all experimental units. The leaf sampling mechanism was to select one leaf with the widest leaf area from each plant sample. The results of the calculations for all samples showed that the highest leaf area was found in the 14% greenhouse treatment with a nutrient concentration of 50% LOF and 50% AB mix, with an average value of 103.65 cm^2.

Results of variance analysis show that the addition of LOF affect the leaf area of lettuce plants. Nutrients in LOF always play an important role in plant survival. Adequate nutrient requirements will affect the metabolism of plant organs. Plants that metabolize well will increase cell division in plant tissues, especially leaves, which will expand, thereby increasing leaf area. This statement is consistent with the observation results, which show that adding 50% LOF

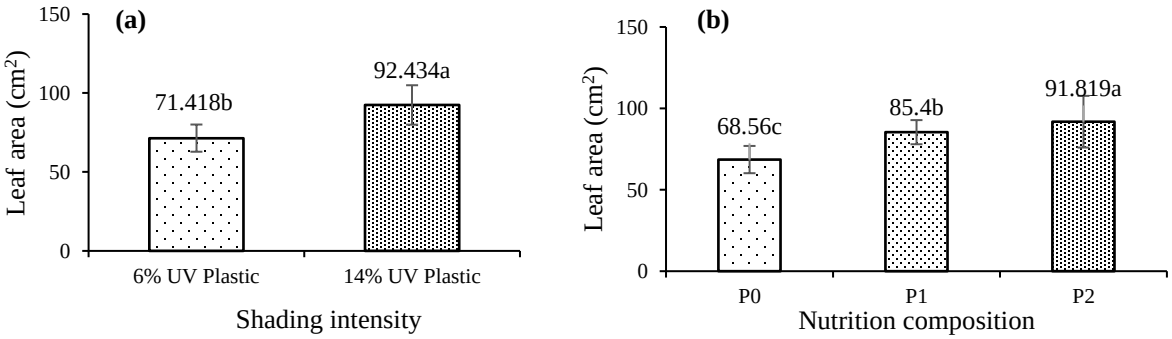

Figure 10. Effect of treatment factors on the leaf area of lettuce: (a) Shading intensity, (b) Nutrient composition

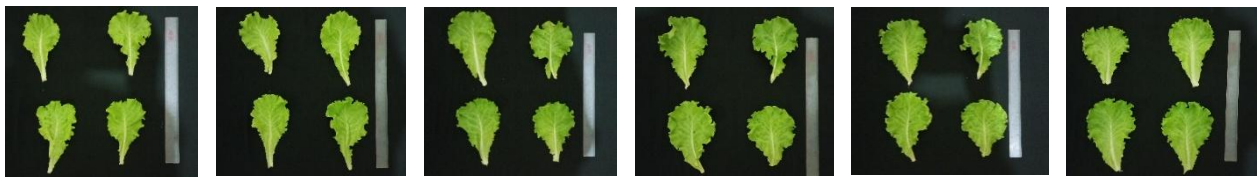

Figure 11. Leaf samples of lettuce from different treatments: (a) N1P0; (b) N1P1; (c) N1P2; (d) N2P0; (e) N2P1; (f) N2P2

to the hydroponic nutrient solution can produce the highest leaf area in lettuce plants. Shade levels can also affect leaf area, as lower radiation intensity and increased auxin activity promote radiation absorption (Jamilah & Bukhari, 2022).

3.8. Canopy Area

Canopy lettuce is the part of the plant consisting of stems, leaves, and branches that form an umbrella-like top layer. Canopy area was measured after harvesting lettuce plants at 45 days after sowing. Canopy area was measured using ImageJ software for each sample. Canopy area is the upper part of a plant, including all leaves and branches that form the plant layer. The plant canopy acts as a radiation trap and protects plants from environmental factors such as rain and wind. The canopy of a plant is formed from several crowns that cover an area. The canopy area value indicates the plant's ability to store and absorb carbon (Rosa, 2021). The canopy area can be influenced by the genetics of the type of lettuce being cultivated. The research was conducted using Claribel lettuce produced by Bejo Zaden B.V. (The Netherlands). Claribel lettuce is a type of butterhead lettuce having thinner leaves and an overlapping leaf structure (Zhou *et al*., 2024). These conditions cause the canopy area of this type of lettuce to be smaller than other types of lettuce.

(a) (b) (c)

Figure 12. Sample of canopy area of lettuce from different treatments: (a) NIP2; (b) N2P1; (c) N2P0

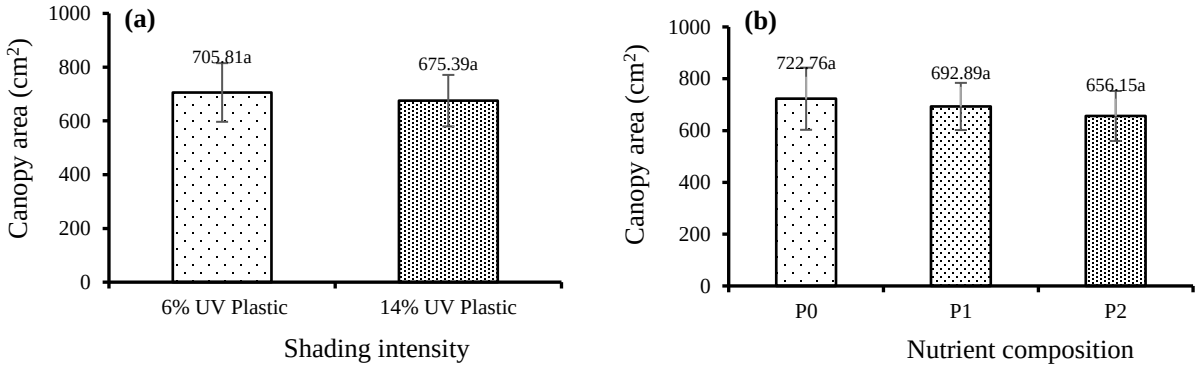

Figure 13. Effect of treatment factors on the leaf area of lettuce: (a) Shading intensity, (b) Nutrient composition

3.9. Leaf Color

Observation results of lettuce leaf color using the Munsell color chart indicator show varying notation values. The observation results show that the majority color in the tested samples is strong yellow green, both in greenhouses with 6% and 14% UV plastic shade. All leaf samples are in the 5 GY (Green Yellow) category. In general, these results show differences in radiation intensity and nutrient composition.

The treatment applied in this study showed no significant effect on the color of lettuce leaves. The observed samples had color notations that were not significantly different. The results showed that the color of leaves on both 6% and 14% UV plastic was almost the same. Leaf color notation consists of value and chroma, which indicate the brightness level of a leaf. Based on the greenhouse observation results, the majority of the 6% samples had a color notation of 5/8, but

the 14% greenhouse showed that the majority of samples had a color notation of 6/8. The difference in color notation variation indicates that radiation intensity can affect the brightness of leaf color. Leaves that produce brighter colors generally have a larger surface area and grow at higher radiation intensity levels (Hutugalung *et al*., 2021).

3.10. Level of Crispness

Crispness level is measured by conducting an organoleptic test. This test involves 15 respondents to assess the crispness of harvested lettuce. Each group of lettuce was prepared with four samples and all respondent provided the crispness score using Likert scale. Crispness level is categorized into 5 levels, where each category has a fixed score according to Akbar (2024), namely very crispy (5), crispy (4), fairly crispy (3), less crispy (2), and uncrispy (1). The crispness score provided by respondents through questionnaire were tabulated and then analyzed using ANOVA. The results is presented in Figure 14. Based on ANOVA, no single factor as well as its interaction is statistically significant on the organoleptic crispness score of lettuce with significance value of $p = 0.086$ for shading, $p = 0.548$ for nutrient composition, and $p = 0.631$ for interaction. showed that shading did not significantly affected the organoleptic score for lettuce crispness.

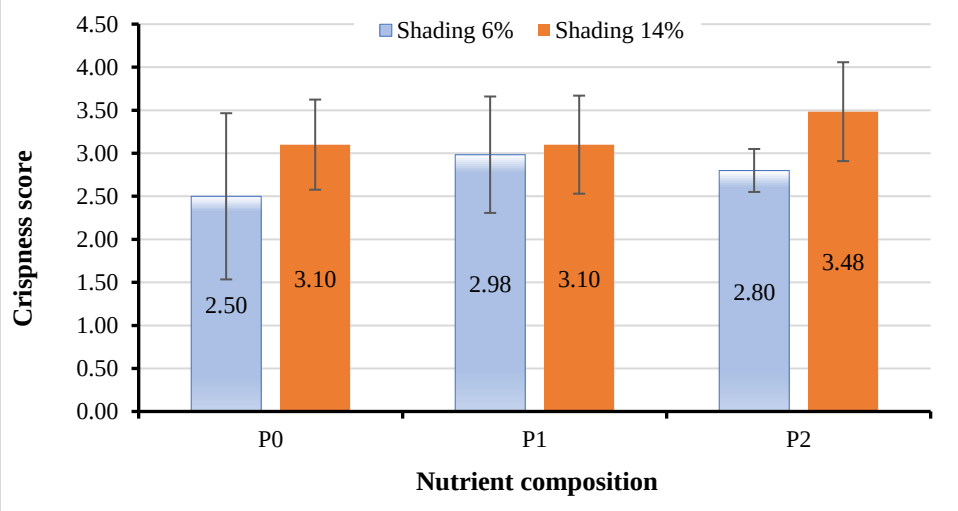

Figure 14. Effect of shading and nutrient on the crispness score of lettuce

From Figure 14, all lettuces cultivated with UV plastic 6% got crispness score between 2 (less crispy) to 3 (fairly crispy). Although statistically not significant, lettuce cultivated with UV plastic 14% tend to result in higher crispness level with score between 3 (fairly crispy) to 4 (crispy). The crispness of lettuce leaves is primarily determined by turgor pressure (the internal water pressure within the cell vacuoles) that pushes against the cell walls, making them rigid. Factors influencing this include moisture management, temperature, cultivation methods, harvest and post harvest handling. Hutugalung *et al*. (2021) reported that lettuce plants cultivated with shading have lower radiation intensity and can affect crispness levels because the leaves produced are thinner. The addition of LOF affect the nutrient solution that may also influence crispness levels in hydroponic lettuce. For example, Lee *et al*. (2025) concluded that increasing nutrient solution resulted in the increase of greenness and crispness of lettuce leaf. The organoleptic test results in this research, however, was performed with untrained respondent that may influence the preference scores.

4. CONCLUSION

Based on the research conducted, it was found that the combined interaction of AB Mix and LOF nutrients and the use of shade can affect leaf width, root volume, and chlorophyll content in lettuce plants. The use of 6% and 14% UV plastic shade affects plant height, leaf width, root volume, chlorophyll content, number of leaves, leaf area, leaf color, and crispness level in lettuce plants, but does not affect canopy area. The application of the combination of AB Mix and LOF nutrients can affect plant height, leaf width, root volume, chlorophyll content, number of leaves, leaf area, leaf

color, and crispness level in lettuce plants, but does not affect plant canopy area. Generally 14% UV Plastic is more recommended for hydroponic in Situbondo because it yields better results in terms of plant height, leaf width, root volume, weight, leaf area, and crispness of lettuce. The addition of 25% LOF increased leaf count, chlorophyll content, and fresh weight, which directly affect the quality and appearance of the product, and potentially increase the market value of the lettuce. Additional research is recommended to examine a wider range of LOF variations and parameters such as yield and nutrient content, to support more comprehensive improvement in the market value of lettuce.

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AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
IP	✓	✓		✓			✓	✓		✓				✓
TR					✓				✓					
BCF			✓						✓		✓			
ALS						✓							✓	
BK						✓							✓	
US												✓		
TWS		✓			✓									
WM							✓							

C: Conceptualization	Fo: Formal Analysis	O: Writing - Original Draft	Fu: Funding Acquisition
M: Methodology	I: Investigation	E: Writing - Review & Editing	P: Project Administration
So: Software	D: Data Curation	Vi: Visualization	
Va: Validation	R: Resources	Su: Supervision	

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