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The Effect of Planting Media and Nutrient Flow on the Growth of Hydroponic Lettuce with the NFT System

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ABSTRACT

Lettuce is a type of vegetable plant that is consumed by the wide community. Hydroponic lettuce cultivation has become an alternative as land area decreases as a result of land-use conversion. This research aims to determine lettuce growth which is influenced by the type of planting media and nutrient discharge. This study was conducted at the Greenhouse Emak Farm and Hidroponik Wadungasri, Waru District, Sidoarjo Regency, East Java, adopting a Split Plot Design with the main plot of nutrient solution discharge (L) consisting of 3 levels, namely L_1 *= 1.5 L/min;* L_2 *= 2 L/min;* L_3 *= 2.5 L/min. The subplot is the planting media (M) consisting of 4 types, namely* M_1 *= rockwool;* M_2 *= rice husk charcoal;* M_3 *= cocopeat;* M_4 *= fern. The observed variables comprised leaf number, leaf area, plant height, stem diameter, total plant biomass, stem and leaf biomass, root biomass, harvest index, and plant age. The results indicated that the combination of fern-based growing media and a nutrient solution flow rate of 1.5 L/min produced the most favorable outcomes for all measured parameters, with the exception of the harvest index. Nutrient flow rate of 1.5 L/min was recommended for hydroponic using fern growing media.*

1. INTRODUCTION

Lettuce (*Lactuca sativa* L.) is a widely cultivated leafy vegetable with a long history of use as both a medicinal plant and a food source since approximately 4,500 BC. It is commonly consumed fresh, particularly in salads and other raw vegetable preparations, and is a valuable source of carbohydrates, dietary fiber, and protein. In general, in 1000 grams of lettuce consists of carbohydrates 2.9 g, fat (0.2 g), protein (1.2 g), calcium (Ca, 22 g), phosphorus (P, 25 g), iron (Fe, 0.5 g), vitamin A (165 mg), vitamin B (0.04 g), and vitamin C (8.0 g) (Utami *et al*., 2024).

Urban farming is the cultivation of plants, the processing of plant products, and the distribution or marketing of food and agricultural products in urban areas, both in cities and around urban areas, especially horticultural, livestock and fisheries commodities (Pribadi & Shodiq, 2023). Urban agriculture has the opportunity to utilize limited land in the agricultural sector, especially the cultivation of vegetables, fruit and medicinal plants. One type of urban agricultural cultivation is hydroponics. Hydroponic lettuce cultivation is the best solution to meet consumer demand throughout the year. Hydroponics is a plant cultivation technique that uses water as a medium and does not use soil as a plant medium (Pribadi & Shodiq, 2023), and there is no need to use large areas of land to cultivate plants. The land crisis that occurs due to land conversion has the potential to lose land for planting, so hydroponic cultivation can be an alternative for agricultural development. Key factors influencing the success of hydroponic plant cultivation include the type of growing medium and the nutrient solution flow rate in the Nutrient Film Technique (NFT) system.

Planting media that are often used in NFT hydroponic cultivation include: rockwool, husk charcoal, hydrotone, cocopeat, ferns, and broken bricks, where each type of planting media has its own advantages and disadvantages.

However, in general, the planting media that must support the success of hydroponic cultivation is one that is porous and has good aeration and can store the necessary nutrients.

A commonly used growing medium is rockwool, which has the ability to retain large amounts of water and oxygen needed for root growth and nutrient absorption (Susilawati, 2019). However, this medium is relatively expensive, making it less recommended for small-scale hydroponics. Some alternative growing media for hydroponics include rice husk charcoal, cocopeat (coconut fiber), and ferns. According to Hidayat *et al*. (2021), the use of rice husk charcoal resulted in superior plant growth and lettuce leaf area, showing increases of 32% and 230.87%, respectively, compared to rockwool. Fern growing media is superior to other growing media because it is thought to contain N, C, H, and silica, and is suitable for use in all growth phases, from shoot propagation, seedling development, juvenile development, to flowering. Furthermore, this medium offers optimal aeration and drainage, with numerous air cavities allowing roots to develop freely (Muzafri *et al*., 2023).

The Nutrient Film Technique (NFT) is a hydroponic irrigation method in which a thin layer of nutrient solution, typically not exceeding 3 mm in depth, continuously flows and partially submerges plant roots for 24 hours. One of the key principles of the NFT system is the nutrient solution flow rate, which plays an important role in regulating nutrient delivery to plants. Plants closest to the inlet (nutrient solution inlet) will absorb a lot of nutrients and oxygen, while plants furthest from the inlet will receive less nutrients and oxygen. Improper disposal of nutrient solutions can cause nutrient absorption to not occur properly. Excreting the nutrient solution too quickly can inhibit the absorption of nutrients by the roots, whereas if it is too slow it can cause nutrient deposition. According to Dalastra *et al*. (2020), nutrient solution discharge affects the wet and dry weight and nutrient content of lettuce plants, thereby supporting plant growth and development.

Plants in a hydroponic system obtain nutrients through the growing media used. Nutrients that are not absorbed optimally can be caused by various types of media. This is because the characteristics of one medium and another medium do not have the same ability to absorb nutrients by plant roots. In addition, good nutrient absorption depends on the release of an optimal nutrient solution. Optimal disposal of nutrient solution is able to maintain humidity, porosity and good aeration of the root environment. Nutrient absorption will not work well if it is not supported by appropriate planting media and disposal of nutrient solutions. Hence, this research was carried out to examine the effects of various growing media types along with appropriate nutrient solution flow rates on lettuce plant growth and development. Referring to the established background and problem formulation, this research is expected to enhance farmers' understanding of the optimal combination of growing media and nutrient flow rates that most effectively promote the growth of hydroponic lettuce in an NFT system.

2. MATERIALS AND METHODS

2.1. Research Location

The study was conducted between July and August 2024 at Emak Farm Garden and the Wadungasri Hydroponic Greenhouse in Waru District, Sidoarjo Regency, East Java. The site is located at an elevation of approximately 4 m above sea level and has an average temperature of 27 °C.

2.2. Preparation

Preparation of tools and materials used. The tools used include digital scales, NFT system hydroponic installation, water pump, TDS meter, EC meter, pH meter, knife, hand sprayer, measuring cup, seedling tray, rockwool punch media, netpot, ruler, stationery and camera. The research materials used Grand Rapids lettuce seeds, charcoal husks, ferns, AB Mix nutrients, cocopeat, rockwool and water.

2.3. Design of Experiment and Procedure

This research applied a factorial experimental approach involving two factors, organized using a split-plot design. The main plot factor was nutrient solution flow rate (L), consisting of three levels: L1 = 1.5 L min^{-1}, L2 = 2.0 L min^{-1}, and L3 = 2.5 L min^{-1}. The subplot factor was planting medium (M), which included four types: M_1 = rockwool, M_2 = husk charcoal, M_3 = cocopeat, and M_4 = fern. Each treatment combination was repeated three times, yielding a total of 36 experimental units. Every unit consisted of five plants, with three plants selected as samples for observation.

The determination of nutrient solution flow rate was initiated by installing water pumps with different output capacities in separate NFT installations. The height of the NFT installation is one meter with a capacity of four gutters eight meters long and a slope of 5 cm. One gutter has 37 planting holes with a distance between holes of 15 cm and one planting hole with a diameter of 4 cm.

The cocopeat growing medium was thoroughly rinsed with water to eliminate tannin residues, while the fern-based medium was sterilized using a bactericide and fungicide solution for one hour before being drained. The rockwool and husk charcoal planting media do not need to be sterilized because the rockwool is processed at high temperatures until it is sterile, while the pathogenic microbes in the husk charcoal media have died during the burning process. Rockwool media was cut using a knife measuring 2 x 2 x 2 cm (square). Each planting medium is put into a different seedling tray.

Sowing begins by inserting one lettuce seed into the planting hole of rockwool, husk charcoal, cocopeat, fern media in the seedling tray and watering it with water. Seeding is carried out for 2 weeks or after the lettuce seedlings appear 2-3 leaves. Transplantation is carried out when the lettuce seedlings are 14 days after planting (DAT) and there are 3 young leaves, by inserting the lettuce plants into the planting hole in the hydroponic installation.

The AB Mix nutrient solution is given with a concentration of 0.8 dS m^{-1} - 1.5 dS m^{-1} when the lettuce plants are 1 to 15 DAT, while the concentration is 1.5 dS m^{-1} - 2.0 dS m^{-1} when the lettuce plants are aged 15 to 30 DAT. After all the nutrients have been provided to each water tank, the water pump machine can be turned on. Previous studies have demonstrated that lettuce performance is strongly influenced by nutrient solution flow rate. Dalastra *et al*. (2020) identified 1 L min^{-1} as the most favorable rate for supporting lettuce growth and development, whereas Soares *et al*. (2020) showed that a higher flow rate of 1.5 L/min maximized fresh and dry shoot biomass and enhanced leaf area.

Maintenance activities comprised the regulation of nutrient concentration in the AB Mix solution, pH adjustment, replanting, and plant protection. Harvesting of lettuce plants is carried out at 45 days after planting (DAT) by lifting the plant net pot, then cleaning the planting medium by washing it until the plant roots are visible. The criteria for lettuce to be ready for harvest are yellowish green leaves, wide, significantly wavy leaf edges, and visible stem segments between the leaves.

2.4. Parameters and Measurements

The parameters evaluated in lettuce plants comprised plant height (cm), leaf number (count), leaf area (cm^2), stem diameter (mm), fresh biomass mass (g), aboveground biomass mass (g), root mass (g), harvest index, and harvest time (days). Plant height was recorded weekly by measuring the distance from the stem base to the tip of the longest leaf. Leaf count was performed from the youngest fully expanded leaves to the oldest ones. Leaf area (L) was calculated by measuring the length and width of the leaf (Hidayat *et al*., 2020).

$$L + p \times l \times k \tag{1}$$

where p represents leaf length (cm), determined as the distance from the leaf base to the apex of the longest leaf; l denotes leaf width (cm), measured at the midpoint of the leaf at its widest section; and k is a constant with a value of 0.58.

The diameter of the stem was measured at the lower part, about 5 cm above the ground, using a caliper (mm). Total wet weight was observed by weighing samples of lettuce plants. Observation of stem and leaf weight was carried out by weighing samples of lettuce plants whose roots had been cut. Root weighting is done by weighing samples of lettuce plant roots without stems and leaves. The harvest index was calculated according to Nurfaida (2019) as follow.

$$\text{Harvest Index} = \frac{\text{wet weight of stem+leaf wet weight}}{\text{total plant weight}} \tag{2}$$

2.5. Analysis

The experimental data were evaluated using analysis of variance (ANOVA) based on the applied experimental layout, specifically the Split Plot Design (RPT). When the F-test revealed significant differences, post hoc comparisons were performed using the Honestly Significant Difference (HSD) test at a 5% significance level ($\alpha = 0.05$).

3. RESULTS AND DISCUSSION

Plant nutrients dissolved in water are mostly inorganic and ionic forms that will bind to complex compounds in the form of mineral salts forming formulas that will be used in hydroponic systems (Hidayat *et al*., 2024). Baiyin *et al*. (2021) reported that applying a nutrient solution flow rate of 1.5 L/min enhanced nutrient absorption in fern-based media, especially for certain essential nutrients. Nutrients absorbed by root hairs will affect photosynthesis. If water absorption is small, photosynthesis cannot be optimal. The stem functions as a transport pathway that delivers nutrients absorbed by the roots to the leaves and distributes photosynthetic products from the leaves to all parts of the plant, with the leaves serving as the primary site of photosynthesis. Photosynthesis requires water and carbon dioxide to produce oxygen and carbohydrates. Oxygen is needed to support life and plants for the respiration process that will produce carbon dioxide, water, and energy. According to Pribadi & Shodiq (2023), oxygen is necessary for plants to generate ATP, and nutrients are absorbed to support the metabolic processes occurring in the plant body.

Dissolved nutrients are bound in the nitrogen-containing fern growing medium, enriching its nutrient content. Nitrogen increases leaf expansion, which facilitates photosynthesis, leading to an increase in leaf number and area, which positively correlates with stem and leaf weight. Photosynthesis produces carbohydrates, one of which is sucrose, a carbon source for plant growth and development, transported by the phloem. The phloem distributes the results of photosynthesis to all parts of the plant. Fern growing media maintains optimal temperatures in the root zone (Manggas, 2021). Maintaining optimal temperatures influences oxygen availability, as noted by Suprayogi & Suprihati (2021), who reported that higher temperatures result in lower oxygen content in water.

3.1. Plant Height

The analysis results indicated a significant interaction between planting media treatments and nutrient solution flow on lettuce plant length at 14, 21, and 28 DAT. As presented in Table 1, the use of fern-based growing media in combination with a nutrient solution flow rate of 1.5 L/min resulted in the greatest plant length values. This is because the fern planting medium is able to absorb more plant nutrients when the nutrient flow rate is low (1.5 l/min) and has a positive impact on increasing leaf growth (leaf length, number, and area), so that the photosynthesis process takes place longer, more efficiently, and produces more photosynthates for overall lettuce plant growth (Candra *et al*., 2020). According to Mulyadi (2016), fern planting media has the capacity to hold 16.54 ml/liter of water. A nutrient solution supplied at a rate of 1.5 L/min improves nutrient absorption in fern-based media, especially nitrogen. This result agrees with the findings of Baiyin *et al*. (2021), who demonstrated that appropriate flow rates promote enhanced nitrogen uptake.

At 7 days after transplanting (DAT), the planting media factor alone had a significant effect. As shown in Table 2, lettuce grown in fern-based media exhibited the greatest plant length at 7 DAT and differed significantly from plants

Table 1. The effect of planting media type and the nutrient flow rate on the length (cm) of lettuce plants at age 14 to 28 DAT

Plant Age (DAT)	Type of Planting Media	Nutrient Solution Flow Rate (l/min)		
		L_1 (1.5 l/min)	L_2 (2 l/min)	L_3 (2.5 l/min)
14	M_1 (rockwool)	6.33ab	7.56b	5.89a
	M_2 (husk charcoal)	9.28c	9.89c	9.44c
	M_3 (cocopeat)	6.67ab	6.56ab	7.11ab
	M_4 (fern)	12.39d	10.44cd	11.44d
HSD 5%		1.42		
21	M_1 (rockwool)	10.78ab	31.00b	11.33b
	M_2 (husk charcoal)	13.78c	11.78bc	13.44c
	M_3 (cocopeat)	10.56ab	9.11a	11.78bc
	M_4 (fern)	17.22d	12.56bc	12.00bc
HSD 5%		1.92		
28	M_1 (rockwool)	15.67c	12.33ab	13.33bc
	M_2 (husk charcoal)	18.78d	14.33bc	15.11c
	M_3 (cocopeat)	12.89b	10.67a	13.67bc
	M_4 (fern)	22.72e	15.44c	13.56bc
HSD 5%		1.93		

Note: Mean values that share identical letters at the same observation time indicate no significant differences according to the HSD test at the 5% significance level.

Table 2. The effect of the planting medium type and the nutrient flow rate on the length of lettuce plants at age 7 DAT

Type of Planting Media	L_1 (1.5 l/min)	L_2 (2 l/min)	L_3 (2.5 l/min)	Average
M_1 (rockwool)	2.44	3.78	3.22	3.15a
M_2 (husk charcoal)	5.78	5.94	5.67	5.80b
M_3 (cocopeat)	2.78	3.44	2.72	2.98a
M_4 (fern)	6.78	6.56	6.00	6.44c
Average	5.96a	6.19a	6.22a	

Note: Mean values that share identical letters at the same observation time indicate no significant differences according to the HSD test at the 5% significance level.

cultivated in other growing media. However, the nutrient solution flow treatment did not show a significant difference in the length of lettuce plants aged 7 DAT. This is because plants aged 7 DAT have short roots and do not have many lateral roots so that the nutrient solution provided is not absorbed optimally. According to Purba *et al*. (2021) Plants that have short roots have the effect of reducing the volume of nutrients absorbed by the roots because the roots are not able to absorb water better than plants that have long roots. The formation of lateral roots will increase the number of roots which will expand the distribution of roots so that nutrient uptake is more optimal (Amir, 2016).

3.2. Number of Leaves

The results of the analysis revealed a statistically significant interaction between planting media types and nutrient solution flow rates on lettuce leaf number across observation periods of 7–28 days after transplanting (DAT). As presented in Table 3, the highest leaf counts were recorded in plants grown using fern-based media combined with a nutrient solution flow rate of 1.5 L/min. This response is associated with the inherent nutrient content of fern media, particularly nitrogen, which is essential for leaf formation and expansion. Zidny (2023) reported that fern planting media contains approximately 0.63% nitrogen, contributing to improved nutrient availability and supporting optimal plant quality. These results are in agreement with the findings of Arzita *et al*. (2023), who demonstrated that nitrogen has a direct function in protein synthesis, thereby stimulating vegetative growth and chlorophyll development. In addition, supplying the nutrient solution at a flow rate of 1.5 L/min enhances the absorption of essential elements by plants. This observation is consistent with Amin *et al*. (2022), who reported increased uptake of N, P, K, Ca, and Mg in lettuce grown under a nutrient solution flow rate of 1.5 L/min.

Table 3. Effects of planting media types and nutrient solution flow rates on leaf number in lettuce plants from 7 to 28 DAT

Plant Age (DAT)	Type of Planting Media	Nutrient Solution Flow Rate (L/min)		
		L_1 (1.5 l/min)	L_2 (2 l/min)	L_3 (2.5 l/min)
7	M_1 (rockwool)	2.89ab	2.78ab	2.67a
	M_2 (husk charcoal)	3.56b	3.78b	4.11bc
	M_3 (cocopeat)	2.67a	2.67a	2.67a
	M_4 (fern)	4.89c	4.11bc	3.89b
HSD 5%			0.84	
14	M_1 (rockwool)	5.89bc	5.67b	5.22a
	M_2 (husk charcoal)	5.56b	5.78b	5.78b
	M_3 (cocopeat)	4.78a	4.56a	5.56b
	M_4 (fern)	6.78c	5.44a	5.56b
HSD 5%			0.89	
21	M_1 (rockwool)	6.78ab	5.78ab	6.33ab
	M_2 (husk charcoal)	7.56b	6.67ab	7.00ab
	M_3 (cocopeat)	5.67a	5.78ab	8.56bc
	M_4 (fern)	9.67c	6.78ab	6.33ab
HSD 5%			1.63	
28	M_1 (rockwool)	8.33ab	7.33a	8.67ab
	M_2 (husk charcoal)	11.22c	9.00ab	8.78ab
	M_3 (cocopeat)	7.44ab	11.33c	11.56c
	M_4 (fern)	14.22d	9.22b	9.22b
HSD 5%			1.88	

Note: Mean values that share identical letters at the same observation time indicate no significant differences according to the HSD test at the 5% significance level.

3.3. Leaf Area

The analysis revealed a significant interaction between planting media type and nutrient solution application on lettuce leaf area. As presented in Table 4, the largest leaf area was observed in plants grown in fern-based media combined with a nutrient solution flow rate of 1.5 L/min. This effect is attributed to the natural nutrients in fern media, particularly nitrogen, which support leaf development. These results are consistent with Safitri *et al*. (2020), who found that higher nitrogen levels promote broader leaves and a deeper green coloration in plants.

Table 4. Effects of planting media type and nutrient solution flow rate on the leaf area (cm²) of lettuce plants

Type of Planting Media	**AB Mix Nutrient Solution Flow Rate**		
	1.5 l/min	**2 l/min**	**2.5 l/min**
M_1 (rockwool)	699.02ab	577.94ab	656.50ab
M_2 (husk charcoal)	1089.27c	693.52ab	767.21ab
M_3 (cocopeat)	519.47a	788.61b	878.23bc
M_4 (fern)	**1780.69d**	586.56ab	683.13ab
HSD 5%		267.51	

Note: Mean values that share identical letters at the same observation time indicate no significant differences according to the HSD test at the 5% significance level.

3.4. Stem Diameter

The analysis revealed a significant interaction between planting media treatments and nutrient solution application on the stem diameter of lettuce plants. As indicated in Table 5, the combination of fern-based growing media with a nutrient solution flow rate of 1.5 L/min resulted in the largest stem diameters. Stem thickening is associated with increased carbohydrate availability. Carbohydrates, produced during photosynthesis, are partially utilized for growth and partly serve as substrates in respiration to generate energy. This energy supports cell division and expansion, leading to stem diameter enlargement. These findings are supported by Sari *et al*. (2019), who reported that adequate carbohydrate and protein levels contribute to optimal development of roots, stems, and leaves.

Table 5. Effect of planting media type and the nutrient flow rate on the stem diameter (mm) of lettuce plants

Type of Planting Media	**AB Mix Nutrient Solution Flow Rate**		
	1.5 l/min	**2 l/min**	**2.5 l/min**
M_1 (rockwool)	10.47a	11.30ab	12.03ab
M_2 (husk charcoal)	13.97b	13.37b	11.87ab
M_3 (cocopeat)	10.40a	11.77ab	11.83ab
M_4 (fern)	**14.10b**	12.47ab	11.67ab
HSD 5%		2.10	

Note: Mean values that share identical letters at the same observation time indicate no significant differences according to the HSD test at the 5% significance level.

3.5. Total Plant Weight

The analysis revealed a significant interaction between planting media and nutrient solution flow on the total weight of lettuce plants. As presented in Table 6, the combination of fern-based media with a nutrient solution flow rate of 1.5 L/min resulted in the highest total plant weight. This treatment also positively influenced plant height, leaf number and area, and stem diameter, collectively contributing to the overall increase in lettuce biomass. These results are consistent with Pardosi *et al*. (2014), who reported that greater plant height, leaf number, leaf area, and stem diameter together enhance total plant weight, reflecting the cumulative growth of vegetative parts. The application of nutrient solutions directly affects the availability of water and essential nutrients for plant uptake. This process makes nutrients available and converts them into forms that can be absorbed by plant roots, supporting balanced metabolic activity and promoting plant growth. This is consistent with Hidayat *et al*. (2020), who reported that optimal water absorption stimulates secondary meristem activity, particularly enhancing vegetative growth such as increased leaf number and area, as well as stem diameter

Table 6. Influence of planting media type and nutrient solution flow rate on the total weight (g) of lettuce plants

Type of Planting Media	AB Mix Nutrient Solution Flow Rate		
	1.5 l/min	**2 l/min**	**2.5 l/min**
M_1 (rockwool)	79.56a	91.78ab	90.89ab
M_2 (husk charcoal)	110.56b	98.89ab	98.33ab
M_3 (cocopeat)	78.78a	89.11ab	107.22b
M_4 (fern)	**128.44b**	96.11ab	91.78ab
HSD 5%		23.27	

Note: Mean values that share identical letters at the same observation time indicate no significant differences according to the HSD test at the 5% significance level.

3.6. Above Ground Biomass Weight

The analysis showed a significant interaction between planting media and nutrient solution flow on the stem and leaf weight of lettuce. As presented in Table 7, the highest stem and leaf biomass was observed in plants grown in fern-based media combined with a nutrient solution flow rate of 1.5 L/min. This is attributed to the fact that this combination also produced the greatest leaf number and leaf area. An increase in leaf number is accompanied by a corresponding increase in stem and leaf weight. These results are consistent with Nurholis *et al.* (2023), who noted that variations in leaf characteristics influence plant biomass due to differences in photosynthetic capacity, which drives biomass accumulation. The increasing leaf area indicates the higher ability of the leaves to receive and absorb sunlight so that photosynthesis and the energy produced are also higher.

Table 7. Effect of planting media type and the nutrient flow rate on the above ground biomass weight (g) of lettuce plants

Type of Planting Media	AB Mix Nutrient Solution Flow Rate		
	1.5 l/min	**2 l/min**	**2.5 l/min**
M_1 (rockwool)	66.89a	78.33ab	75.89ab
M_2 (husk charcoal)	94.00b	82.56ab	82.22ab
M_3 (cocopeat)	65.33a	74.67ab	91.00b
M_4 (fern)	**111.00b**	80.56ab	76.00ab
HSD 5%		23.16	

Note: Mean values that share identical letters at the same observation time indicate no significant differences according to the HSD test at the 5% significance level.

3.7. Root Weight

The analysis revealed a significant interaction between planting media and nutrient solution flow on the root weight of lettuce plants. As shown in Table 8, the highest root biomass was obtained in plants grown using fern-based media combined with a nutrient solution flow rate of 1.5 L/min. This effect is attributed to the fern medium's ability to effectively retain nutrients at this flow rate, which also impacts the availability of dissolved oxygen. These results align with Suprayogi & Suprihati (2021), who reported that the nutrient solution flow rate influences dissolved oxygen levels in the water, and are further supported by Purba *et al.* (2021), who noted that nutrients absorbed by the roots are translocated throughout the plant, and if not retained by the growing medium, they continue to move freely within plant tissues. Dissolved oxygen affects good plant root weight because it will facilitate the performance of lettuce plant roots for respiration so that the energy produced from plant root respiration can be used for nutrient absorption. This is consistent with Pribadi & Shodiq (2023), who explained that oxygen is vital for plants to generate energy in the form of ATP, while nutrients are taken up and used to support various metabolic processes within the plant.

Table 8. Effect of planting media type and the nutrient flow rate on the root weight (g) of lettuce plants

Type of Planting Media	AB Mix Nutrient Solution Flow Rate		
	1.5 l/min	**2 l/min**	**2.5 l/min**
M_1 (rockwool)	12.67a	13.44ab	15.00ab
M_2 (husk charcoal)	16.56b	16.33b	16.11b
M_3 (cocopeat)	13.44ab	14.44ab	16.22b
M_4 (fern)	**17.44b**	15.56ab	15.78b
HSD 5%		3.01	

Note: Mean values that share identical letters at the same observation time indicate no significant differences according to the HSD test at the 5% significance level.

3.8. Harvest Index

The analysis showed that there was no significant interaction between planting media and nutrient solution flow on the harvest index of lettuce. Table 9 shows that the single factor of planting media and nutrient solution discharge produces a harvest index that is not significantly different from other types of planting media. This is because the two treatments together are able to produce relatively similar plant growth and production between one treatment combination and the other. This is consistent with Bahri *et al*. (2020), who reported no interaction between harvest index variables, likely because both treatments effectively support plant growth and production, resulting in less variation in growth outcomes.

Table 9. Effect of planting media type and the nutrient flow rate on the harvest index of lettuce plants

Planting Media	L_1 (1.5 l/min)	L_2 (2 l/min)	L_3 (2.5 l/min)	Average
M_1 (rockwool)	0.84	0.85	0.83	0.84a
M_2 (husk charcoal)	0.84	0.84	0.84	0.85a
M_3 (cocopeat)	0.83	0.84	0.85	0.84a
M_4 (fern)	0.86	0.84	0.82	0.85a
Average	0.83A	0.84A	0.85A	

Note: not significantly different

3.9. Harvest Age

The analysis revealed a significant interaction between planting media and nutrient solution flow on the root weight of lettuce plants. As presented in Table 10, the combination of fern and husk charcoal media with a nutrient solution flow rate of 1.5 L/min resulted in the most favorable harvest life parameters for lettuce. This is because the planting media and the release of nutrient solutions as plant nutrition managers are the keys to the success of cultivating hydroponic lettuce plants with the NFT system. Healthy plant physiology is positively associated with plant height, leaf number and size, and total plant weight, making it a key factor in achieving high crop productivity. According to Syaban *et al*. (2023), the quality of plants seen from their physiological characteristics affects the harvest age of the plant, where when the plant is physiologically mature (in accordance with the plant harvest criteria) the plant can be harvested even if it does not meet the requirements, generally specified time. Nutrient solution is a critical factor that significantly affects both the quality and yield of plants (Hidayat *et al*., 2024).

Table 10. Effect of planting media type and the nutrient flow rate on the harvest age (DAT) of lettuce plants

Type of Planting Media	AB Mix Nutrient Solution Flow Rate		
	1.5 l/min	2 l/min	2.5 l/min
M_1 (rockwool)	30.33b	32.33c	34.00d
M_2 (husk charcoal)	**27.67a**	31.67bc	34.00d
M_3 (cocopeat)	32.00c	35.00d	35.00d
M_4 (fern)	**27.67a**	32.00c	35.00d
HSD 5%		1.17	

Note: Mean values that share identical letters at the same observation time indicate no significant differences according to the HSD test at the 5% significance level.

4. CONCLUSION

The findings showed that the combination of fern-based planting media and a nutrient solution flow rate of 1.5 L/min produced the most optimal results for lettuce in terms of plant height, leaf number, leaf area, stem diameter, total plant weight, stem and leaf weight, root weight, and harvest age. In hydroponic systems, nutrients are present in inorganic ionic forms that are readily soluble. Supplying the nutrient solution at a flow rate of 1.5 L/min improves nutrient uptake, which is essential for photosynthesis. Agar absorbs nutrients and air, while simultaneously distributing the products of photosynthesis throughout the plant stem. Nitrogen in the fern medium increases leaf size and supports photosynthesis, which produces carbohydrates for growth. Maintaining an optimal temperature in the root zone is crucial for oxygen availability and overall plant health. Based on the study results, it is recommended to carry out further research using rice husk charcoal as the planting medium with a nutrient solution flow rate of 2 L/min.

AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
ADS	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RH	✓	✓		✓	✓					✓		✓		
DUP	✓	✓		✓	✓					✓		✓		

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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