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An Aeration Pressure, Plant Spacing, And Dissolved Oxygen For Growth Of Lettuce (Lactuca Sativa L.) Plants In Floating Hydroponics

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ABSTRACT

The successful growth of lettuce plants in floating hydroponics is controlled by the availability of oxygen and the level of plant density. Dissolved oxygen in water is controlled by the aeration pressure provided in hydroponics. This research aims to determine The impact of aeration pressure on the growth of lettuce (Lactuca sativa L) in a floating hydroponic system, considering different planting spacings. The research employed a Randomized Block Factorial Design (RAKF), incorporating two treatment factors: plant spacing (Factor A) with two different levels, and aeration pressure (Factor B) with three different levels. Each combination was replicated three times. And oxygen linear regression analysis for dissolved (Dissolved Oxygen) and aeration pressure. The conclusion of the research showed that The conclusions of this research were The highest production of lettuce was achieved with treatment A2B3, using a planting distance of 30 cm and aeration pressure of 16 kPa, resulting in a total fresh weight of the plants of 82.89 g, Lettuce planted at a spacing of 30 cm outperformed lettuce planted at 20 cm in terms of canopy width, root length, and total fresh weight, 3.The aeration pressure increases, the concentration of dissolved oxygen in the water also increases, the canopy width, root length, and total fresh weight of lettuce. The average dissolved oxygen ranged from 7.17 to 7.22 mg/l, so the aeration pressure correlates with increased dissolved oxygen levels, suggesting that higher aeration pressure correlates with increased dissolved oxygen levels. The Suggestion was Further research should be conducted on the appropriate size of the nutrient solution reservoir concerning the aeration pressure applied.

***Keywords**: Lettuce (Lactuca Sativa L.), Dissolved Oxygen, Aeration Pressure, Plant Spacing, Floating Hydroponics*

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INTRODUCTION

The number of Indonesia's population is increasing, and the need for horticultural commodities, especially vegetables, every year is always increasing in line with the increasing demand for lettuce (*Lactuca sativa* L.) (Pujisiswanto and Pangaribuan, 2010). Lettuce (*Lactuca sativa* L.) is a plant that is very popular among urban communities. This is because, in addition to being nutritious, it is also good for the body's vitamin needs (Cahyani, Hasibuan and Ch, 2019). Lettuce (*Lactuca sativa L.*) is one of the vegetable plants that are consumed by the public in fresh form (Warganegara *et al.*, 2015). Furthermore, lettuce is very effective when grown using hydroponics (Hamyana, Budianto and Bukori, 2023). Lettuce is cultivated hydroponically without using soil (Mardina et al., 2019) and utilizes a nutrient solution as a source of essential elements (Zenita, 2019); (Umarie, 2020); (Sipin Solis and U. Gabutan, 2023). One of the nutrients commonly used in hydroponics is AB Mix fertilizer (Nazara *et al.*, 2023);(Lestari, Rahayu and Mulyaningsih, 2022); (Romalasari and Sobari,

2019) which is capable of increasing plant height, leaf count, and leaf width. (Zahrima, Sutariati and Rakian, 2019). In order to grow well, plants cultivated hydroponically need to get complete nutrients, which consist of macro (N, P, K, Ca, Mg, S) and micro (Cl, Mn, Fe, Cu, Zn, B, and Mo) elements (Warjoto *et al*, 2020).

Hydroponics has various types of cultivation techniques, one of which is floating hydroponics, which is a form of urban farming (Puspitahati, Andini and Hp, 2021)**.** The advantages of hydroponics include high efficiency in water and nutrient use (Ariananda and Nopsagiarti, 2020); (Wiratama, Suroso and Wijaya, 2023), the installation is cheaper to create, and materials are easily obtainable by using styrofoam above the basin (Sagita, 2020); (Yunindanova, Darsana and Putra, 2018) thus enabling the creation of higher dissolved oxygen content. (Riza Linda, 2018). On the other hand, its weakness is that the roots submerged in the nutrient solution create a saturated water condition, causing the plants to lack oxygen, which affects the growth process of the plants (Virha and Bayfurqon, 2020); (Pudjiwati and Asmina, 2020).

This research provides a new technique, namely the use of high concentrations of dissolved oxygen (20-30 mg/L) achieved through high-pressure pure oxygen(Suyantohadi *et al.*, 2010);(Zheng, Wang and Dixon, 2007), which significantly improves lettuce growth, especially under low temperature conditions and oxygen enrichment methods, such as aquarium air pumps, to determine its effectiveness on the yield and quality of lettuce(Kurashina *et al.*, 2019). Additionally, the use of saturated dissolved oxygen as a growth regulator adds an innovative approach to hydroponic systems. From an economic standpoint, better oxygenation techniques can increase lettuce yields, with some methods yielding up to 202.4 grams per plant(Ercan and Bayyurt, 2014); (Lin *et al.*, 2013) These improvements provide higher economic returns, while encouraging cost-effective and resource-efficient hydroponic systems. Non-economic benefits include improved plant health, higher nutritional quality of produce(Nicola *et al.*, 2015), and reduced reliance on chemical fertilizers, encouraging more sustainable farming practices and contributing to environmental sustainability.

According to (Krisna *et al.*, 2017), the higher the concentration of dissolved oxygen in the nutrient solution, the better the absorption of nutrients by the plant roots in floating hydroponics. Plants that are provided with oxygen in their growing media will have better growth compared to those that are not given oxygen, thus shortening the harvest time (Surtinah, 2016), Meanwhile, according to (Fauzi and Putra, 2013) applying aeration pressure of 12 kPa to the root system of lettuce plants will result in a dissolved oxygen content of 12.23 mg/l, which can shorten the harvest age. Plant respiration is closely linked to the amount of oxygen available in the water; insufficient oxygen can lead to rapid deterioration and death of the plant roots. To mitigate this problem, it is essential to enhance dissolved oxygen levels by employing an aerator (Puspitahati *et al.*, 2022).

In addition to aeration pressure and dissolved oxygen, one of the supporting factors in plant growth is the plant density level. The density of plants affects growth and the components of crop yield and can effectively absorb nutrients (Vera, Turmudi and Suprijono, 2020); (Kurniawati, 2020a). If the spacing of plants in the net potholes is too close, the plant roots will compete for nutrient absorption, resulting in a low coefficient of plant uniformity (Puspitahati, Trianita and Purnomo, 2022), while the canopies will compete for light and air, especially oxygen (Valdhini and Aini, 2018). Given the information provided, it is crucial to carry out a study that examines how different aeration pressures affect dissolved oxygen levels and how these variations, combined with different planting distances, impact the growth of lettuce (Lactuca sativa L) in a floating hydroponic system.

RESEARCH METHOD

The research was conducted from May 2021 to September 2021 at the plant house on Jalan Padang Selasa, Bukit Besar, Palembang, and at the Basic Fisheries Laboratory, Department of Fisheries, Agriculture, Faculty Sriwijaya University. The tools used in this research were 1) Aerator Set, 2) Punching Tool, 3) Writing Instruments, 4) Floating Raft System Tank, 5) DO Meter, 6) Camera, 7) Seedling Tray, 8) Netpot, 9) Ruler,

10) pH Meter, 11) Stirring Spoon, 12) Styrofoam, 13) TDS EC Meter, 14) Thermohygrometer, 15) Analytical Scale. The materials used in the implementation of this research were: 1) Water, 2) Lettuce seeds, 3) AB mix nutrients, and 4) Rockwool.

This research uses a Factorial Randomized Block Design (FRBD) with two factors, as follows: The first factor is planting distance (D) which consists of two levels, namely: D1 = 20 cm, D2 = 30 cm, and the second factor is aeration pressure (P) which consists of three levels, namely: P1 = 12 kPa, P2 = 14 kPa, B3 = 16 kPa. Each treatment is replicated three times. The research data are examined using analysis of variance (ANOVA) with a 5% significance threshold, and the results are further analyzed with the Honest Significant Difference (HSD) test at the same 5% level. A tabulation method is employed to observe the effects of dissolved oxygen, ph, and EC during each week of plant growth. The parameters observed in this study are as follows: Plant Height (cm), Number of Leaves (pieces), Canopy Width (cm), Root Length (cm), Total Fresh Weight Per Plant (g), and dissolved oxygen (ml/l).

RESULTS AND DISCUSSION

The environmental conditions during the research were as follows: the air temperature was 28.1°C, the air humidity was 72.5%, the pH of the nutrient solution ranged from 6.5 to 6.6, and the electrical conductivity (EC) of the nutrient solution was between 1070 and 1103 mS/cm. The results of the significance test indicate that planting distance does not significantly impact plant height, whereas aeration pressure does have a significant effect on plant height, as detailed in Table 1.

Table 1. BNJ 5% test table of the effect of planting distance on the height of lettuce plants (cm) from 1 MST to 4 WAP.

Plant Age	Factor	Average	BNJ 0,05
1 WAP	D1	0,828 a	0,131
	D2	0,882 a	0,131
2 WAP	D1	2,453 a	0,164
	D2	2,476 a	0,164
3 WAP	D1	7,435 a	0,288
	D2	7,515 a	0,288
4 WAP	D1	11,608 a	0,248
	D2	11,785 a	0,248

Note: The average values followed by different letters in the same column indicate a significant effect.

The results of the significance test indicate that planting distance does not have a significant effect on plant height, suggesting that other factors, such as environmental conditions or genetic factors, might play a more important role in determining plant height. On the other hand, aeration pressure significantly impacts plant height, as supported by research showing that soil aeration can affect plant growth by enhancing root oxygen availability, which is crucial for root respiration and nutrient absorption (Ben-Noah and Friedman, 2018);(Li et al., 2019).

According to the BNJ test results at a 5% significance level, planting distances ranging from 1 to 4 WAP do not significantly impact plant height. However, the standard planting distance for lettuce, which is 14 cm at 35 HST, does influence leaf growth and plant height (Vu Phong et al., 2019). On the other hand, aeration pressure does have a noticeable effect on plant height. At 4 MST, the tallest plant was observed in treatment P0 at 11.909 cm, while the shortest was in treatment P1 at 11.401 cm. The results of the 5% got the effect of aeration pressure on plant height (in cm) from 1 to 4 WAP are presented in Table 2.

Table 2. The Results of the 5% BNJ test on the effect of aeration pressure on plant height (cm) from 1 to 4 WAP.

Plant Age	Factor	Average	BNJ 0,05
1 WAP	P3	0,728 a	0,252
	P2	0,773 ab	0,252
	P1	0,914 ab	0,252
	P0	1,006 b	0,252
2 WAP	P3	2,217 a	0,315
	P2	2,274 a	0,315
	P0	2,651 b	0,315
	P1	2,717 b	0,315
3 WAP	P3	7,125 a	0,552
	P2	7,299 ab	0,552
	P1	7,664 ab	0,552
	P0	7,813 b	0,552
4 WAP	P1	11,401 a	0,476
	P2	11,626 ab	0,476
	P3	11,850 ab	0,476
	P0	11,909 b	0,476

Note: The average values followed by different letters in the same column indicate a significant effect.

The application of aeration pressure on plants can assist in root growth and obtain dissolved oxygen in water, thereby enhancing the absorption of nutrients(Virha and Bayfurqon, 2020), specifically, the nutrients N, P, and K found in the AB MIX nutrient content that can promote plant growth. (Soleha, Suroso and Wijaya, 2021). The impact of planting distance on the number of lettuce leaves, as determined by the BNJ 5% significance level, is detailed in Table 3.

Table 3. BNJ 5% Test of the effect of planting distance on the number of lettuce leaves from 1 MST to 4 WAP.

Plant Age	Factor	Average	BNJ 0,05
1 WAP	D1	5,5 a	0,390
	D2	5,7 a	0,390
2 WAP	D1	7,8 a	0,475
	D2	8,2 a	0,475
3 WAP	D1	10,9 a	0,468
	D2	11,5 b	0,468
4 WAP	D1	13,8 a	0,468
	D2	14,3 b	0,468

Note: The average values followed by different letters in the same column indicate a significant effect.

The BNJ test at the 5% level showed that the planting distance treatment significantly affected the number of plant leaves between 3 and 4 WAP, a greater planting distance can enhance the number of leaves because the wider the planting distance, the lower the competition among roots in absorbing nutrients (Kurniawati, 2020a). The AB Mix solution can stimulate leaf growth if its absorption by the roots is done optimally (Sudewi *et al.*, 2022), allowing each plant to grow well. The results of the BNJ 5% test on aeration pressure against the number of lettuce leaves can be seen in Table 4.

Table 4. BNJ 5% effect of aeration pressure on the number of leaves of lettuce aged 1 to 4 WAP

Plant Age	Factor	Average	BNJ 0,05
1 WAP	P0	5,2 a	0,748
	P1	5,3 ab	0,748
	P2	5,8 ab	0,748
	P3	6,0 b	0,748
2 WAP	P0	7,4 a	0,911
	P1	7,7 ab	0,911
	P2	8,5 b	0,911
	P3	8,5 b	0,911
3 WAP	P1	10,5 a	0,897
	P2	10,8 ab	0,897
	P3	11,7 b	0,897
	P4	11,8 b	0,897
4 WAP	P1	13,3 a	0,897
	P2	13,8 a	0,897
	P3	14,2 ab	0,897
	P4	14,8 b	0,897

Note: Average values followed by different letters in the same column indicate a significant effect.

In Table 4 of the BNJ 5% test results, it is evident that aeration pressure significantly affected the number of lettuce leaves from 1 to 4 WAP. This is because higher levels of dissolved oxygen in the water improve nutrient absorption for plants and support the respiration process, leading to an increased number of plant leaves (Dharmayanti, Sumiyati and Yulianti, 2021).

Aerating nutrient solutions generally enhances plant growth, including leaf production, by improving nutrient and water uptake. Specifically, aeration boosts the absorption of essential nutrients such as potassium (K), phosphorus (P), and magnesium (Mg)(Camarillo *et al.*, 2020). Aeration pressure also influences plant respiration and photosynthesis processes. It has been observed that as total pressure increases in high humidity, the respiration rate decreases linearly, while the net photosynthesis rate can increase up to 1.6 times due to higher total pressure and CO2 partial pressure (Takeishi *et al.*, 2013). At low pressures, gas diffusivity increases, impacting the rate of CO2 absorption and water transpiration through the stomata. Stomatal conductance, which regulates gas exchange, is inversely related to stomatal opening, thereby affecting plant respiration (Gohil, Correll and Sinclair, 2011).

Table 5. BNJ 5% test table for the effect of planting distance on the canopy width (cm) of lettuce plants aged 1 to 4 WAP.

Plant Age	Factor	Average	BNJ 0,05
1 WAP	D1	3,990 a	0,276
	D2	4,239 a	0,276
2 WAP	D1	16,260 a	0,677
	D2	16,986 b	0,677
3 WAP	D1	28,037 a	0,407
	D2	30,000 b	0,407
4 WAP	D1	29,372 a	0,191

	D2	31,200 b	0,191

Note: Average values in the same column that are marked with different letters indicate a significant difference.

The BNJ test results at a 5% significance level reveal that planting distance significantly affects canopy width and plant growth at ages 2 to 4 WAP. It is suggested that plants will perform better if spaced appropriately, allowing them to absorb nutrients more effectively and grow to their full potential. Consequently, increasing the planting distance will benefit both the canopy width and overall plant growth. At 4 WAP, treatment P3 had an average canopy width of 30.721 cm, which was not different from treatment B2 but differed from treatments P0 and P1. Treatment P0 had an average canopy width of 30.232 cm, which was not different from P3 but differed from treatments P1 and P2. According to (Puspitaningrum et al., 2012), the dissolved oxygen content an important role in the plant respiration process, which causes the plant canopy to become wider. DO levels are affected by photosynthesis and respiration. Plants produce oxygen during photosynthesis, which can increase DO levels in the surrounding water. On the other hand, respiration consumes oxygen, so DO levels decrease(Sunardi et al., 2020);(Akomeah and Lindenschmidt, 2017) An increase in DO can lead to a larger leaf area index (LAI), which is a measure of leaf area per unit area of soil and is directly related to the width of the canopy.(Ouyang et al., 2021).

Table 6. BNJ 5% test results for the impact of aeration pressure on lettuce canopy width (cm) at ages 1 to 4 WAP.

Plant Age	Factor	Average	BNJ 0,05
1 WAP	P0	3,958 a	0,530
	P3	4,039 a	0,530
	P1	4,167 a	0,530
	P2	4,293 a	0,530
2 WAP	P0	16,060 a	1,299
	P3	16,429 a	1,299
	P1	16,935 a	1,299
	P2	17,069 a	1,299
3 WAP	P0	28,457 a	0,780
	P3	28,925 ab	0,780
	P1	29,258 b	0,780
	P2	29,436 b	0,780
4 WAP	P0	30,232 a	0,366
	P3	30,364 a	0,366
	P1	30,566 ab	0,366
	P2	30,721 b	0,366

Note: Average values in the same column with differing letters denote a significant difference.

The results of the 5% BNJ test on the effect of planting distance on the root length (cm) of lettuce plants can be seen in Table 7.

Table 7. BNJ 5% test results for the influence of planting distance and aeration pressure on the root length (cm) of lettuce plants.

Factor	Average	BNJ 0,05 0,759	Factor	Average	BNJ 0,05 1,455
D1	19,275	a	P0	19,868	A
D2	22,144	b	P1	20,178	Ab

			P2	21,294	B
			P3	21,681	B

Note: Average values within the same column that have different letters indicate a significant difference.

The BNJ test results at a 5% significance level show that increasing the planting distance generally leads to longer root lengths in lettuce plants. When the planting distance is wider, there is more space for growth, which means the plants do not have to compete for nutrients from the AB Mix. Conversely, the closer the planting distance, the less air is available for the plants to absorb (Rajagukguk, Aswandi and M. Si., 2023). Meanwhile, the influence of aeration pressure on the root length of lettuce plants showed that an increase in aeration pressure and oxygen content leads to an increase in root length. The increase in temperature causes a decrease in DO levels (Puspitahati and Andica, 2023). The results of the BNJ 5% test on the effect of planting distance on the fresh weight total (g) of lettuce plants can be seen in Table 8.

Table 8. BNJ 5% test table on the effect of planting distance on the fresh weight total (g) of lettuce plants

Factor	Average	BNJ 0,05 3,653	Factor	Average	BNJ 0,05 7,007
D1	50,354	a	P0	59,777	a
D2	78,250	b	P1	62,332	ab
			P2	67,223	b
			P3	67,875	b

Note: Average values in the same column marked with different letters reflect a significant difference.

The BNJ test results at a 5% significance level show that treatment A1 differs significantly from treatment D2. Increasing the planting distance leads to a higher total fresh weight of the plants. Furthermore, the BNJ test indicates that treatment P0 is comparable to treatment P1 in terms of significance, while treatments P2 and P3 exhibit significant differences. According to (Kurniawati, 2020b), adequate dissolved oxygen in the root zone is crucial for optimal plant growth.

From the observations, the highest dissolved oxygen content was provided by the aeration pressure treatment of 16 kPa, which ranged from 7.17 to 7.22 mg/l, as shown in Figure 1

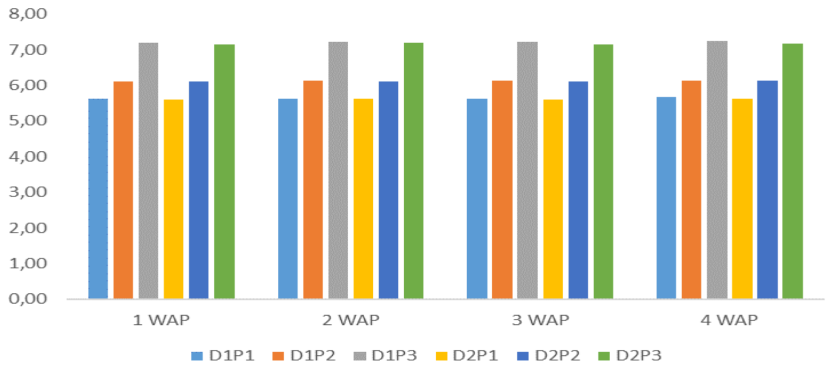

Figure 1. The Average Dissolved Oxygen Value for each treatment (mg/l)

In Figure 1, the trend of the dissolved oxygen (DO) graph against the aeration pressure applied is linear. It is evident that as the aeration pressure increases, the dissolved oxygen value tends to rise as well. According to (Pudjiwati and Asmina, 2020), The higher the dissolved oxygen content in hydroponic water, the better the respiration process of the plants. Aeration can help plant roots obtain dissolved oxygen in water and enhance the nutrient content that can be absorbed by the plants (Virha and Bayfurqon, 2020).

Aeration affects the dissolved oxygen (DO) content in hydroponics for plant growth. This process involves transferring oxygen from the air into the water, which can be done through surface or subsurface aeration, using air bubbles(Baiyin et al., 2021). The aeration efficiency is affected by the size of the bubbles, the surface area, the flow rate, and the diameter of the nozzle, all of which contribute to increased oxygen transfer. In addition, aerators and venturi are very effective in increasing DO levels, as they can improve the displacement of water and air masses, in hydroponic systems(Zhang et al., 2024). Correlation between Dissolved Oxygen (mg/l) and Aeration Pressure shown on Figure 2.

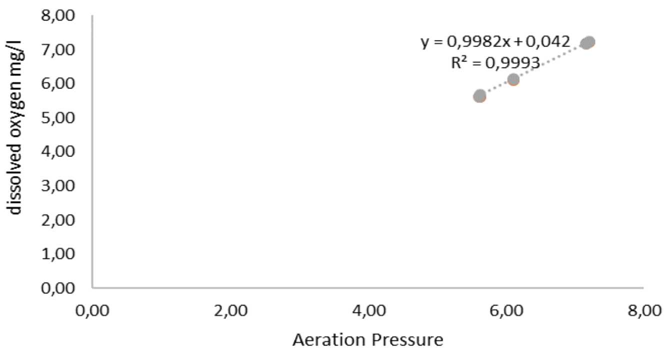

Figure 2. Correlation between Dissolved Oxygen (mg/l) and Aeration Pressure

Figure 2 showed that the relationship between dissolved oxygen (DO) levels and aeration pressure has a linear relationship shown by an R of 0.9993, which means that as the aeration pressure increases, the concentration of dissolved oxygen in the water also increases. This happens because the higher aeration pressure increases the amount of oxygen transferred from the air into the water, thereby increasing the availability of oxygen for the plant's roots .

The energy needed for root growth and ion absorption comes from respiration which requires oxygen. Without sufficient oxygen for respiration, the absorption of water and ions stops, and the plant roots die (Krisna *et al.*, 2017). Plants that receive sufficient oxygen will have better growth, and the movement of nutrients will circulate, allowing the plants to absorb nutrients effectively (Puspitahati *et al.*, 2022). According to Paramitha *et al*, (2014), Dissolved oxygen levels are affected by factors such as atmospheric pressure, temperature, salinity, water movement, as well as photosynthesis and respiration processes.

CONCLUSION AND SUGGESTIONS

The conclusions of this research The highest production of lettuce was achieved with treatment A2B3, using a planting distance of 30 cm and aeration pressure of 16 kPa, resulting in a total fresh weight of the plants of 82.89 g, lettuce planted at a spacing of 30 cm outperformed lettuce planted at 20 cm in terms of canopy root length, width, and total fresh weight, The aeration pressure increases, the concentration of dissolved oxygen in the water also increases, the canopy width, root length, and total fresh weight of lettuce. The average dissolved oxygen ranged from 7.17 to 7.22 mg/l, so the aeration pressure correlates with increased dissolved oxygen levels.

Further research should be conducted on the appropriate size of the nutrient solution reservoir concerning the aeration pressure applied.

REFERENCES

Alvarado-Camarillo, D. *Et Al.* (2020) 'Response Of Hydroponic Lettuce To Aeration, Nitrate And Potassium In The Nutrient Solution', *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science*, 70(4), Pp. 341–348. Available At: Https://Doi.Org/10.1080/09064710.2020.1730430.

Akomeah, E. and Lindenschmidt, K.E. (2017) ‘Seasonal variation in sediment oxygen demand in a Northern chained River-lake system’, Water (Switzerland), 9(4). Available at: https://doi.org/10.3390/w9040254.

Ariananda, B. And Nopsagiarti, T. (2020) ‘Hidroponik Sistem Floating’, *Jurnal Green Swarnadwipa*, 9(2), Pp. 185–195.

Baiyin, B. et al. (2021) ‘Study on plant growth and nutrient uptake under different aeration intensity in hydroponics with the application of particle image velocimetry’, Agriculture (Switzerland), 11(11). Available at: https://doi.org/10.3390/agriculture11111140.

Ben-Noah, I. And Friedman, S.P. (2018) ‘Review And Evaluation Of Root Respiration And Of Natural And Agricultural Processes Of Soil Aeration’, *Vadose Zone Journal*, 17(1), Pp. 1–47. Available At: Https://Doi.Org/10.2136/Vzj2017.06.0119.

Cahyani, N.A., Hasibuan, S. And Ch, R.M. (2019) ‘Pengaruh Urin Kelinci Dan Media Tanam Berbeda Terhadap Pertumbuhan Dan Produksi Tanaman Selada (Lactuca Sativa) Secara Hidroponik Dengan Sistem Wick’, *Bernas Agricultural Research Journal*, 15(1), Pp. 20–28.

Dharmayanti, N.K.S.A., Sumiyati, S. And Yulianti, N.L. (2021) ‘Pengaruh Pemberian Aerasi Terhadap Pertumbuhan Dan Produksi Selada (Lactuca Sativa L.) Pada Sistem Hidroponik Rakit Apung (Floating Raft Hydroponic System)’, *Jurnal Beta (Biosistem Dan Teknik Pertanian)*, 10(1), P. 121. Available At: Https://Doi.Org/10.24843/Jbeta.2022.V10.I01.P12.

Ercan, N. And Bayyurt, R. (2014) ‘The Effects Of Applications Which Increase The O2 Of The Water On Yield And Quality Of Lettuce Grown In A Floating System’, *Acta Horticulturae*, (1034), Pp. 77–84. Available At: Https://Doi.Org/10.17660/Actahortic.2014.1034.8.

Fauzi, R. And Putra, E.T.S. (2013) ‘Oxygen Enrichment In The Root Zone To Increase The Growth’, *Vegetalika*, 2(4), Pp. 63–74.

Gohil, H.L., Correll, M.J. And Sinclair, T. (2011) ‘Predicting The Effects Of Gas Diffusivity On Photosynthesis And Transpiration Of Plants Grown Under Hypobaria’, *Advances In Space Research*, 47(1), Pp. 49–54. Available At: Https://Doi.Org/10.1016/J.Asr.2010.08.017.

Hamyana, H., Budianto, B. And Bukori, M.I. (2023) ‘The Effect Of Hydroponic Planting System And Media On Lettuce Growth (Latuca Sativa L.)’, In I. Irham, M. Firdaus, And S. De Neve (Eds) *Proceedings Of The International Symposium Southeast Asia Vegetable 2021 (Seaveg 2021)*. Dordrecht: Atlantis Press International Bv, Pp. 36–43. Available At: Https://Doi.Org/10.2991/978-94-6463-028-2_6.

Krisna, B. *Et Al.* (2017) ‘Pengaruh Pengayaan Oksigen Dan Kalsium Terhadap Pertumbuhan Akar Dan Hasil Selada Keriting (Lactuca Sativa L.) Pada Hidroponik Rakit Apung’, *Vegetalika*, 6(4), P. 14. Available At: Https://Doi.Org/10.22146/Veg.30900.

Kurashina, Y. *Et Al.* (2019) ‘Growth Control Of Leaf Lettuce With Exposure To Underwater Ultrasound And Dissolved Oxygen Supersaturation’, *Ultrasonics Sonochemistry*, 51, Pp. 292–297. Available At: Https://Doi.Org/10.1016/J.Ultsonch.2018.10.005.

Kurniawati, D.M. (2020a) ‘Pengaruh Jarak Tanam Dan Pupuk Organik Cair Terhadap Pertumbuhan Dan Hasil Selada Krop (Lactuca Sativa L.)’, *Jurnal Produksi Tanaman*, 8(4), Pp. 411–420.

Kurniawati, D.M. (2020b) ‘Pengaruh Jarak Tanam Dan Pupuk Organik Cair Terhadap Pertumbuhan Dan Hasil Selada Krop (Lactuca Sativa L.)’, 8.

Lestari, I.A., Rahayu, A. And Mulyaningsih, Y. (2022) ‘Pertumbuhan Dan Produksi Tanaman Selada (Lactuca Sativa L.) Pada Berbagai Media Tanam Dan Konsentrasi Nutrisi Pada Sistem Hidroponik Nutrient Film Technique (Nft)’, *Jurnal Agronida*, 8(1), Pp. 31–39. Available At: Https://Doi.Org/10.30997/Jag.V8i1.5625.

Li, Y. *Et Al.* (2019) 'Effect Of Soil Aeration On Root Morphology And Photosynthetic Characteristics Of Potted Tomato Plants (Solanum Lycopersicum) At Different Nacl Salinity Levels', *Bmc Plant Biology*, 19(1), P. 331. Available At: Https://Doi.Org/10.1186/S12870-019-1927-3.

Lin, K.-H. *Et Al.* (2013) 'The Effects Of Red, Blue, And White Light-Emitting Diodes On The Growth, Development, And Edible Quality Of Hydroponically Grown Lettuce (Lactuca Sativa L. Var. Capitata)', *Scientia Horticulturae*, 150, Pp. 86–91. Available At: Https://Doi.Org/10.1016/J.Scienta.2012.10.002.

Nazara, R.V. *Et Al.* (2023) 'Analisis Karakteristik Fisiologis Terhadap Konsentrasi Ab Mix Pada Tanaman Tomat Cherry', *Journal Of Agricultural Sciences*, 21(1), Pp. 12–21.

Nicola, S. *Et Al.* (2015) 'Nitrogen And Aeration Levels Of The Nutrient Solution In Soilless Cultivation Systems As Important Growing Conditions Affecting Inherent Quality Of Baby Leaf Vegetables: A Review', *Acta Horticulturae*, (1099), Pp. 167–177. Available At: Https://Doi.Org/10.17660/Actahortic.2015.1099.17.

Ouyang, Z. et al. (2021) 'Effects of different concentrations of dissolved oxygen on the growth, photosynthesis, yield and quality of greenhouse tomatoes and changes in soil microorganisms', Agricultural Water Management, 245(539), p. 106579. Available at: https://doi.org/10.1016/j.agwat.2020.106579.

Pudjiwati, E.H. And Asmina, D.D. (2020) 'Pengaruh Model Styrofoam Dan Sistem Hidroponik Terhadap Pertumbuhan Dan Hasil Tanaman Pakcoy (Brassica Rapa L.)', *J-Pen Borneo : Jurnal Ilmu Pertanian*, 2(1), Pp. 26–33. Available At: Https://Doi.Org/10.35334/Jpen.V2i2.1512.

Puspitahati, P. And Andica, F. (2023) 'Floating Raft Hydroponic System Using Spray Bars Pumps On Pakcoy Cultivation Growth (Brassica Rapa L.)', In *Proceedings Of The 3rd Sriwijaya International Conference On Environmental Issues, Sricoenv 2022, October 5th, 2022, Palembang, South Sumatera, Indonesia*. *Proceedings Of The 3rd Sriwijaya International Conference On Environmental Issues, Sricoenv 2022, October 5th, 2022, Palembang, South Sumatera, Indonesia*, Palembang, Indonesia: Eai. Available At: Https://Doi.Org/10.4108/Eai.5-10-2022.2328353.

Puspitahati, P., Andini, R. And Hp, R. (2021) 'Urban Farming Dengan Sistem Hidroponik Nft (Nutrient Film Technique) Dipengaruhi Kemiringan Talang Dan Debit Air Pada Produksi Tanaman Pakcoy (Brassica Rapa Chinensis)', *Prosiding Seminar Nasional Lahan Suboptimal Ke-9 Tahun 2021, Palembang 20 Oktober 2021 "Sustainable Urban Farming Guna Meningkatkan Kesejahteraan Masyarakat Di Era Pandemi"*, 1.

Puspitahati, P., Putri, L.S. And Purnomo, R.H. (2022) 'Modifikasi Sistem Hidroponik Rakit Apung Pada Tanaman Sawi Hijau (Brassica Juncea L.)', *Open Science And Technology*, 2(1), Pp. 99–108. Available At: Https://Doi.Org/10.33292/Ost.Vol2no1.2022.63.

Puspitahati, Trianita, M. And Purnomo, R.H. (2022) 'An Nft (Nutrient Film Technique) Hydroponic Irrigation System Design Using Various Gutter Slopes On Pakcoy Plants (Brassica Rapa L.)', *Iop Conference Series: Earth And Environmental Science*, 995(1), P. 012059. Available At: Https://Doi.Org/10.1088/1755-1315/995/1/012059.

Rajagukguk, R.W., Aswandi, A. And M. Si., D.D.H.I.A. (2023) 'Pengujian Tiga Macam Jarak Tanam Pada Hidroponik Sistem Dft Terhadap Pertumbuhan Dan Hasil Panen Dua Varietas Selada Hijau', *Pengujian Tiga Macam Jarak Tanam Pada Hidroponik Sistem Dft Terhadap Pertumbuhan Dan Hasil Panen Dua Varietas Selada Hijau*, Pp. 1–12.

Riza Linda, W.S.R.M. (2018) 'Pertumbuhan Tanaman Selada (Lactuca Sativa L. Var. New Grand Rapids) Menggunakan Teknologi Hidroponik Sistem Terapung (Thst) Tanpa Sirkulasi Dengan Penambahan

Giberelin (Ga3)', *Jurnal Protobiont*, 7(3). Available At: Https://Doi.Org/10.26418/Protobiont.V7i3.29084.

Romalasari, A. And Sobari, E. (2019) 'Produksi Selada (Lactuca Sativa L.) Menggunakan Sistem Hidroponik Dengan Perbedaan Sumber Nutrisi', *Agriprima : Journal Of Applied Agricultural Sciences*, 3(1), Pp. 36–41. Available At: Https://Doi.Org/10.25047/Agriprima.V3i1.158.

Sagita, Y.A. (2020) 'Pengaruh Beberapa Sistem Hidroponik Kultur Air Dan Jumlah Tanaman Per Netpot Pada Pertumbuhan Dan Hasil Tanaman Selada (Lactuca Sativa L.)', *Jurnal Produksi Tanaman*, 8(6), Pp. 594–600.

Sipin Solis, E. And U. Gabutan, J. (2023) 'Hydroponic Lettuce (Lactuca Sativa L. Var. Lalique) Production Using Commercially Available Nutrient Solutions', *International Journal Of Agriculture And Environmental Research*, 09(03), Pp. 330–341. Available At: Https://Doi.Org/10.51193/Ijaer.2023.9306.

Soleha, A., Suroso, B. And Wijaya, I. (2021) 'Efektivitas Sumber Nutrisi Terhadap Pertumbuhan Beberapa Varietas Selada (Lactuca Sativa L.) Pada Sistem Hidroponik', *Agritrop : Jurnal Ilmu-Ilmu Pertanian (Journal Of Agricultural Science)*, 18(2), Pp. 151–161. Available At: Https://Doi.Org/10.32528/Agritrop.V18i2.4065.

Sudewi, S. *Et Al.* (2022) 'Respon Pertumbuhan Tanaman Selada Merah (Lactuca Sativa L. Var. Olga Red) Terhadap Berbagai Jenis Media Tanam Dengan Teknologi Hidroponik Sistem Terapung Tanpa Sirkulasi', *Jurnal Agroteknologi Dan Sains*, 7(1), Pp. 27–38.

Surtinah, S. (2016) 'Keberadaan Oksigen Pada Media Tanam Hidroponik Terhadap Pertumbuhan Tanaman Sayuran (Presence Of Oxygen At Hydroponic Growing Media On The Growth Of Vegetables)', *Jurnal Bibiet*, 1(1), P. 27. Available At: Https://Doi.Org/10.22216/Jbbt.V1i1.1249.

Suyantohadi, A. *Et Al.* (2010) 'Effect Of High Consentrated Dissolved Oxygen On The Plant Growth In A Deep Hydroponic Culture Under A Low Temperature', *Ifac Proceedings Volumes*, 43(26), Pp. 251–255. Available At: Https://Doi.Org/10.3182/20101206-3-Jp-3009.00044.

Sunardi, S. et al. (2020) 'Water corrosivity of polluted reservoir and hydropower sustainability', Scientific Reports, 10(1). Available at: https://doi.org/10.1038/s41598-020-68026-x.

Takeishi, H. *Et Al.* (2013) 'Effects Of Elevated Pressure On Rate Of Photosynthesis During Plant Growth', *Journal Of Biotechnology*, 168(2), Pp. 135–141. Available At: Https://Doi.Org/10.1016/J.Jbiotec.2013.08.012.

Umarie, I. (2020) 'Respons Berbagai Varietas Pakcoy (Brassica Rapa Kultivar Chinensis) Terhadap Sumber Nutrisi Pada Sistem Budidaya Secara Hidroponik', *Agritrop: Jurnal Ilmu-Ilmu Pertanian (Journal Of Agricultural Science)*, 18(2), Pp. 137–150.

Valdhini, I.Y. And Aini, N. (2018) 'Pengaruh Jarak Tanam Dan Varietas Pada Pertumbuhan Dan Hasil Tanaman Sawi Putih (Brassica Chinensis L.) Secara Hidroponik', *Plantropica: Journal Of Agricultural Science*, 2(1), Pp. 39–46. Available At: Https://Doi.Org/10.21776/Ub.Jpt.

Vera, D.Y.S., Turmudi, E. And Suprijono, E. (2020) 'Pengaruh Jarak Tanam Dan Frekuensi Penyiangan Terhadap Pertumbuhan, Hasil Kacang Tanah (Arachis Hypogaea L) Dan Populasi Gulma', *Jurnal Ilmu-Ilmu Pertanian Indonesia*, 22(1), Pp. 16–22. Available At: Https://Doi.Org/10.31186/Jipi.22.1.16-22.

Virha, F.A. And Bayfurqon, F.M. (2020) 'Pengaruh Sistem Aerasi Dan Pemangkasan Akar Terhadap Produksi Bayam Merah (Amaranthus Tricolor L.) Pada Hidroponik Rakit Apung The Effect Of Aeration System And Root Pruning On The Production Of Red Spinach (Amaranthus Tricolor L.) On Floating Raft System Hydroponic', *Agrotekma*, 5(1), Pp. 82–92. Available At: Https://Doi.Org/10.31289/Agr.V5i1.4633.

Vu Phong, L. *Et Al.* (2019) 'Optimizing Plant Spacing And Harvest Time For Yield And Glucosinolate Accumulation In Watercress (Nasturtium Officinale L.) Grown In A Hydroponic System', *Horticultural Science And Technology*, 37(6), Pp. 733–743. Available At: Https://Doi.Org/10.7235/Hort.20190073.

Wiratama, M.T., Suroso, B. And Wijaya, I. (2023) 'Respon Pertumbuhan Dan Produksi Berbagai Varietas Pakcoy (Brassica Rapa L.) Terhadap Pemberian Konsentrasi Zat Pengatur Tumbuh Alami (Air Kelapa) Pada Sistem Rakit Apung', *Jurnal Ilmu-Ilmu Pertanian (Journal Of Agricultural Sciences)*, 21(1), Pp. 22–33.

Yunindanova, M.B., Darsana, L. And Putra, A.P. (2018) 'Variasi Nutrisi Dan Naungan Terhadap Hasil Seledri Dengan Hidroponik Rakit Apung', *Jurnal Agroteknologi*, 9(1), P. 1. Available At: Https://Doi.Org/10.24014/Ja.V9i1.3622.

Zahrima, Z., Sutariati, G.A.K. And Rakian, T.C. (2019) 'Pertumbuhan Tanaman Selada (Lactuca Sativa L.) Yang Dibudidayakan Secara Hidroponik Pada Berbagai Campuran Pupuk Organik Plus Cair Dan Anorganik Ab Mix', *Berkala Penelitian Agronomi*, 7(1), Pp. 65–73. Available At: Https://Doi.Org/10.33772/Bpa.V7i1.9958.

Zenita, Y.M. (2019) 'Pengaruh Media Tanam Dan Konsentrasi Nutrisi Terhadap Pertumbuhan Dan Hasil Tanaman Selada Butterhead (Lactuca Sativa Var. Capitata) Dengan Sistem Hidroponik Substrat', *Jurnal Produksi Tanaman*, 7(8), Pp. 1504–1517.

Zhang, Zhe et al. (2024) 'Root-zone aeration improves fruit yield and quality of tomato by enhancement of leaf photosynthetic performance', Agricultural Water Management, 291. Available at: https://doi.org/10.1016/j.agwat.2023.108639.

Zheng, Y., Wang, L. And Dixon, M. (2007) 'An Upper Limit For Elevated Root Zone Dissolved Oxygen Concentration For Tomato', *Scientia Horticulturae*, 113(2), Pp. 162–165. Available At: Https://Doi.Org/10.1016/J.Scienta.2007.03.011.