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The Application of Nanobubble Technology in Hydroponic SWU-01 to Increase Dissolved Oxygen Concentration and Lettuce Plant Growth

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ABSTRACT

Hydroponic model SWU-01 is a new hydroponic system innovation that regulates watering automatically and independently by utilizing gravity and Archimedes' law. Dissolved oxygen concentration in SWU-01 is only around 3-4.2 mg/L. DO values can be increased by applying nanobubble technology. Ultrafine bubble or nanobubble is a gas bubble in a liquid that has a diameter of <200 nm. The purpose of this study was to determine the effect of nanobubble on dissolved oxygen concentration and growth of lettuce plants cultivated with SWU-01 hydroponics. The experiment used a one-factor randomized complete block design, namely intermittent administration of nanobubble for 15 min every 3 day (P1) and 7 days (P2), and without nanobubble (P0l). The results obtained based on the ANOVA test at the 5% level with the Least Significant Difference (LSD) follow-up test, namely the parameters of fresh weight and number of leaves of lettuce P1 significantly different from P0 and P2, and no significant differences were found in root length, canopy width, and plant height. The P1 treatment is more effective in increasing dissolved oxygen concentration, leaf count, and fresh weight of lettuce produced in lettuce cultivation using the SWU-01 hydroponic system.

1. INTRODUCTION

Lettuce is a horticultural plant that is in great demand by the public because it contains many sources of minerals, vitamins, and fiber (Yang *et al*., 2021). The increasing population in Indonesia and increasing awareness of nutritional needs have caused the consumption and demand for lettuce commodity vegetables to increase rapidly, so lettuce is suitable for cultivation, because it has high prospects and economic value (Mulatsih *et al*., 2021). Lettuce is a seasonal plant that can be cultivated in the highlands or lowlands, and is suitable for hydroponic cultivation system.

The hydroponic system allows for more consistent and efficient lettuce production, with multiple yields compared to conventional methods, with planting that can be done throughout the year without depending on the weather. In addition, high demand comes from the hotel sector, restaurants, to the export market, especially to neighboring countries looking for quality fresh vegetables. The challenge of initial investment costs for hydroponic installations has the potential to be covered by long-term benefits and higher production stability (Rajaseger *et al*., 2018; Kementerian Pertanian, 2020).

Hydroponics is a plant cultivation system without using soil, but using a planting medium in the form of liquid or solid media such as water, cocopeat, rice husk charcoal, rockwool, and others (Lingga, 1984). Hydroponic plant cultivation is a modern technology in agriculture that can be applied in narrow land, saves fertilization costs, and is more efficient in the use of irrigation water (Krestiani & Supriyo, 2022). Currently, there is a new innovation from the hydroponic system, namely Smart Watering Unpad model SWU-01.

Smart Watering Unpad is an automatic and independent watering control tool in a hydroponic system that utilizes gravity and Archimedes' law so that it is free from electricity use. Smart Watering Unpad uses a water control component, namely a float that moves up and down following the water level. Smart Watering Unpad can be applied to various substrate hydroponic systems and water cultures. The recommended level of dissolved oxygen (DO) for hydroponic cultivation is 4 - 8 mg/L (Dwiratna *et al*., 2022). Research by Amin *et al*. (2023), stated that the average DO value of Smart Watering Unpad and Autopot is 3.0 mg/l to 4.2 mg/l, this shows that the Smart Watering Unpad and Autopot systems do not meet the DO needs of plants. High temperatures in the long term can cause a decrease in DO in the nutrient solution (Krisna *et al*., 2017). The DO value in the nutrient solution can be increased by applying nanobubble technology. Nanobubble applications can be found in agriculture, namely that they can significantly increase plant growth in optimizing the growth of shoots and roots that are treated with nutrient deficits in their planting (Iijima *et al*., 2020).

Ultrafine bubbles or Nanobubbles are gas bubbles in liquids that have a diameter of <200 nm and have several unique physical properties (Ebina, et. al., 2013), nanobubble gas bubbles can be dissolved in water for a long time. Nanobubble is a new technology in Indonesia that has become the center of attention because it can be applied in various fields, such as: wastewater treatment, fisheries cultivation, food processing, biomedical engineering, and agriculture (Ahmadi & Khodadadi Darban, 2013). Meanwhile, according to Ebina *et al*. (2013), one of the uses of nanobubble technology in agriculture is to increase plant growth with hydroponic cultivation methods. Nano bubbles effectively increase oxygen content in water and increase vegetative growth through nutrient solutions (Sritontip *et al*., 2022). Therefore, the purpose of this study was to determine the effect of nano bubbles on increasing dissolved oxygen and lettuce growth with SWU-01 hydroponic cultivation.

2. RESEARCH MATERIALS AND METHODS

This experiment used a single-factor randomized block design (RAK), namely the frequency of nanobubble administration for 15 min every 3 days (P1), 7 days (P2), and without nanobubble (P0) with each treatment consisting of 9 plants. This study used the following tools: DO meter, DO sensor, EC sensor, pH sensor, 3 SWU-01 hydroponic installation units, nanobubble generator, ruler, TDS meter, thermohygrometer, and digital scales. The materials used in this study were raw water, lettuce seeds, AB mix nutrients, and rockwool.

2.1. Time and Location of Research

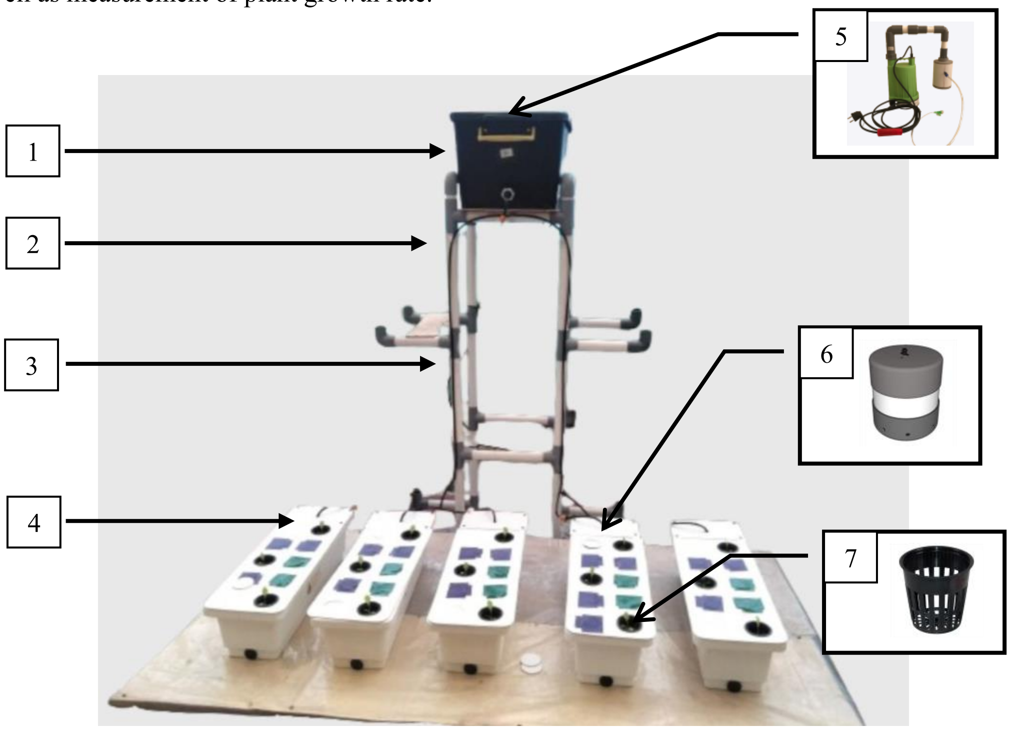
The research was conducted in February-September 2024 at the Urban Farming Laboratory, Faculty of Agricultural Industrial Technology, Padjadjaran University.

2.2. Preparation

Research preparation includes literature studies, preparing tools and materials, installing racks and components of the SWU-01 hydroponic installation as shown in Figure 1.

2.3. Procedure

The study began by determining the generation time and frequency by measuring the DO, pH and EC values in SWU-01 without plants. The nanobubble generator was generated in a 48 L nutrient solution tank for 30 min and measured every 1 hour for 7 days. Lettuce seeds were sown using rockwool seedling media for 10 days until 4 leaves grew. Lettuce seedlings were transplanted into SWU-01 which had been filled with water and AB mix nutrient solution with a ratio of 1:1. The concentration level of the nutrient solution in Parts per Million (PPM) was adjusted to the growth and needs of lettuce plants. The initial DO value was 3.1 mg/L with a temperature of 27.7°C, pH 7.3, and EC 0.206 mS. For 30 DAP, generation was carried out according to the treatment and measurement of DO, pH, EC, temperature and humidity as well as measurement of plant growth rate.



Mark:

1. Reservoir
2. Rack/Tower
3. Irrigation channel
4. Bucket
5. Nanobubble generator
6. Smart valve
7. Net pot

Figure 1SWU-01 hydroponic installation design

2.4. Parameter

The main parameters include DO and temperature values while pH and EC are supporting parameters. Growth rate parameters include plant height, canopy width and number of leaves, while plant productivity parameters include fresh weight of harvest and root length.

2.5. Measurement of DO and Temperature During the Growing Period

Measurements of DO and temperature were conducted three times daily at 8:00 AM, 12:00 PM, and 4:00 PM using a DO meter equipped with DO, pH, and EC sensors. The measurements were carried out under different nanobubble application frequencies: every 3 days (P1), every 7 days (P2), and without nanobubble application (P0).

Figure 2. Measuring canopy width using a ruler

2.6. Measurement of Plant Growth Rate and Productivity

Measurement of growth rates such as plant height and canopy width (length of the growth diameter of all leaves on 1 plant) was carried out every 2 days using a ruler as in Figure 2, while plant productivity parameters such as fresh weight of the harvest, root length and number of leaves were measured at harvest time, namely at 30 days after planting (DAP).

2.7. Data Analysis

Water quality measurement data including DO and temperature values were compiled using Microsoft Excel and analyzed by T-test using SPSS software. Lettuce plant data were compiled using Microsoft Excel and analyzed by ANOVA on SPSS software with a further Least Significant Difference (LSD) test at 5% level to see significant differences.

3. RESULTS AND DISCUSSION

3.1. Dissolved Oxygen Level

Dissolved oxygen levels in the 3 day, 7 day and control nanobubble application frequency treatments had different values as shown in Figure 3. The once 3 day nanobubble application treatment showed greater dissolved oxygen values than the once 7 day treatment and the control. This is because the more often the nanobubbles are added, the more visible the effect on the increase in dissolved oxygen values. This is in line with Wang *et al.* (2021), the increase in dissolved oxygen was higher in High Treatment (application of nanobubbles every 2 h) than in Low Treatment (application of nanobubbles once a day). Sritontip *et al*. (2022), proved that MNBs treatment for 5 min can increase dissolved oxygen which cannot be achieved in treatment without MNBs. One of the formations of nanobubbles is due to the collapse of microbubbles.

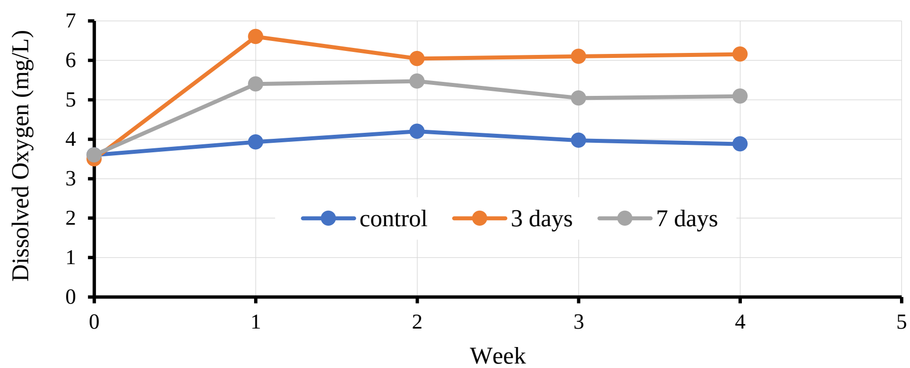


Figure 3. Effect of nanobubble frequency on dissolved oxygen values

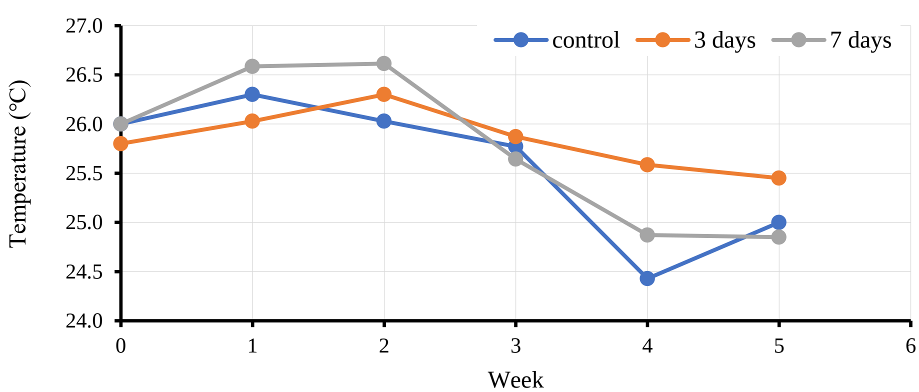


Figure 4. Nutrient Solution Temperature

3.2. Nutrient Solution Temperature

Nutrient solution temperature data in SWU-01 hydroponics shows a fluctuating graph as in Figure 4. The solution temperature for 30 days ranged from 25.5 - 26.3°C in the 3-day frequency treatment, 24.9 - 26.6°C in the 7-day frequency treatment, and 24.4 - 26.3°C in the control. The temperature of the nutrient solution can be affected by environmental conditions. An increase in temperature can affect the level of dissolved oxygen content, when the temperature increases it causes oxygen consumption and results in a decrease in the solubility of dissolved oxygen (Saputri *et al.*, 2014).

3.3. Plant Height Growth

The results showed that the frequency of nanobubble application showed no significant difference in plant height parameters as shown in Figure 5. The highest lettuce plant height at harvest was in the nanobubble application treatment every 3 days and the control, there was an interaction between the concentration of the solution and nanobubble water on plant height growth in the 3rd, 4th, and 5th weeks (Figure 5). This is in line with Thichuto *et al*. (2022), that there was no statistical difference in the height of cherry tomato stems given Micro Nanobubbles (MNB) and without MNB at 14 - 49 DAP, but increased leaf length.

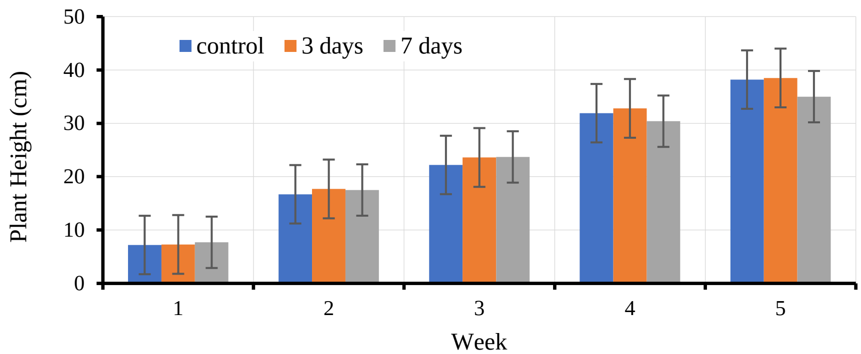


Figure 5. Effect of nanobubbles on plant height growth

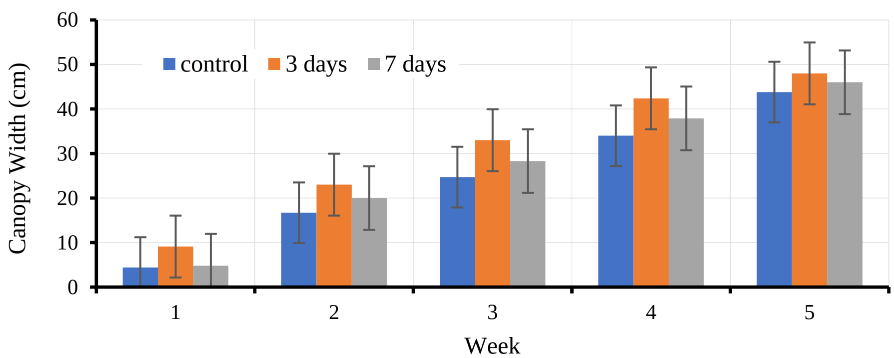


Figure 6. Effect of nanobubble frequency on canopy width growth

3.4. Canopy Width Growth

The treatment of different frequencies of nanobubble application in nutrient solutions showed insignificant results on the growth of the canopy width of lettuce plants as shown in Figure 6. The growth of the canopy width each week experienced an interaction.

3.5. Number of Leaves

The results showed that the frequency of nanobubble showed a significant difference. The addition of nanobubbles to the nutrient solution affected the growth of the number of lettuce leaves in the 2nd, 3rd, 4th, and 5th weeks as shown in Figure 7. The number of lettuce leaves given nanobubbles every 3 days was greater than other treatments.

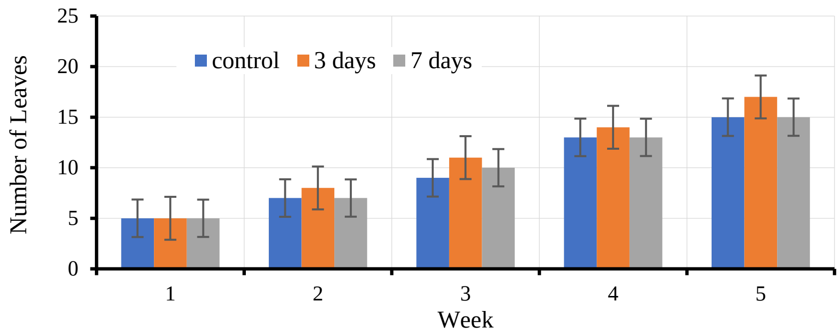


Figure 7. Effect of nanobubble frequency on leaf number growth

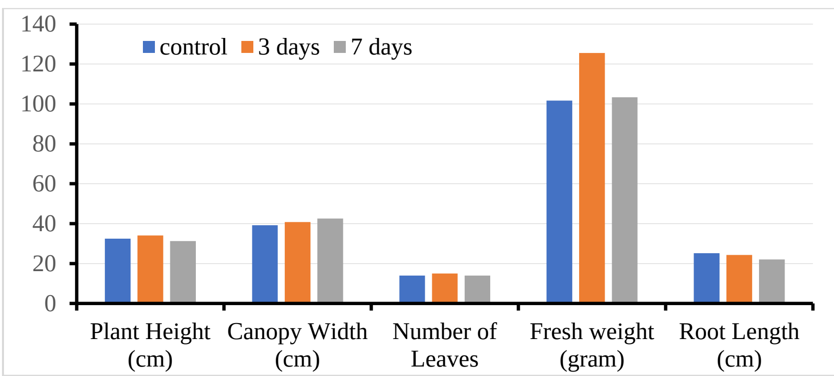


Figure 8. Effect of nanobubble frequency on lettuce growth and harvest yield

3.6. Harvesting Lettuce Plants

The provision of nanobubbles in lettuce cultivation using SWU-01 hydroponics gave greater results than lettuce without nanobubbles or control. Figure 8 shows a graph of lettuce harvest results after 30 DAP. The results of the analysis of lettuce harvest yields given nanobubble frequency treatments every 3 days, every 7 days, and without nanobubbles (control) are shown in Table 1.

Table 1. Lettuce harvest results on SWU-01 hydroponics

Treatment	Nutrition		Plant parameters (at harvest time)				
	EC (mS)	pH	Plant height (cm)	Canopy width (cm)	Number of leaves	Fresh weight (g)	Root length (cm)
Control	1.63^a	6.7^a	32.5^a	39.2^a	14^a	101.67^a	25.2^a
3 days	1.64^a	6.5^a	34.1^a	40.8^a	15^b	125.56^b	24.3^a
7 days	1.65^a	6.6^a	31.3^a	42.6^a	14^a	103.33^a	22.1^a

Note: The same letter notation means there is no significant difference in the LSD test at 5% level.

This study shows that the frequency of nanobubble application and without nanobubble did not have a significant difference in the parameters of plant height, canopy width and root length. The parameter of the growth rate of the number of leaves showed an effect on the frequency of nanobubble application, with the best treatment being a frequency of once every 3 days. Application of nanobubble for 15 min with different frequencies showed significantly different results on the fresh weight of lettuce plants. The higher fresh weight of lettuce was at a frequency of once every 3 days. This is in line with Sritontip *et al*. (2022) that application of MNB for 5 min to green oak lettuce grown hydroponically can increase the fresh weight and dry weight of leaves, as well as the total weight of plants.

Nanobubble treatment increased the fresh weight yield of lettuce at harvest and increased dissolved oxygen in the planting medium. This is in line with Jiang *et al*. (2016) that the application of MNB significantly increased the dissolved oxygen content, thereby increasing plant growth, yield, and quality of lettuce. According to Wang *et al*. (2021), the application of nanobubbles with high intensity can increase nutrient absorption activity and low nutrient residues in the planting medium, resulting in rice yields reaching 2-8% higher than the control. The application of nanobubbles activates energy metabolism (carbon fixation in photosynthetic organisms) which shows an increase in growth energy in rice plants (Wang *et al*., 2021). Nanobubbles can attach to plant roots and attract positively charged nutrient ions from the environment (Takahashi, 2005; Nirmalkar *et al*., 2018) so that they can increase plant growth. In addition, nanobubbles have a negative surface charge which can increase nutrient absorption (Lou *et al*., 2000).

4. CONCLUSION

The application of nanobubble technology in the Smart Watering System SWU-01 hydroponic system significantly increased the concentration of dissolved oxygen in the nutrient solution, which plays an important role in supporting the growth of lettuce plants. Periodic application of nanobubbles for 15 min increased the dissolved oxygen content above 6 mg/L with the best treatment being a frequency of once every 3 days. The application of nanobubbles significantly affected the number of leaves and fresh weight of lettuce produced, but there was no significant difference in plant height, canopy width and root length.

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REFERENCES

Ahmadi, R., & Khodadadi Darban, A. (2013). Modeling and optimization of nano-bubble generation process using response surface methodology. *International Process Journal Nanotechnology*, ***9***(3), 151-162.

Amin, C., Perwitasari, S.D.N., & Amaru, K. (2023). Study of dissolved oxygen quality response in smart watering and autopot systems due to the effect of changes in environmental temperature. *Jurnal Agrotek UMMAT*, ***10***(2), 175-185. https://doi.org/10.31764/jau.v10i2.13347

Dwiratna, S., Amaru, K., & Nanda, M.A. (2022). The potential of hydroponic kit-based growing on a self-fertigation system for Pagoda mustard (*Brassica narinosa* L) production. *The Scientific World Journal*, 1984297, 13 pages. https://doi.org/10.1155/2022/1984297

Ebina, K., Shi, K., Hirao, M., Hashimoto, J., Kawato, Y., Kaneshiro, S., Morimoto, T., Koizumi, K., & Yoshikawa, H. (2013). Oxygen and air nanobubble water solution promote the growth of plants, fishes, and mice. *PLOS ONE*, ***8***(6), e65339 https://doi.org/10.1371/journal.pone.0065339

Iijima, M., Yamashita, K., Hirooka, Y., Ueda, Y., Yamane, K., & Kamimura, C. (2020). Ultrafine bubbles effectively enhance soybean seedling growth under nutrient deficit stress. *Plant Production Science*, ***23***(3), 366-373. https://doi.org/10.1080/1343943X.2020.1725391

Jiang, C., Zhao, S., Song, W., Yamaguchi, T., & Riskowski, G.L. (2016). Effect of micro/nano bubble water on growth, yield and

Kementerian Pertanian. (2020). *Peluang ekspor sayuran hortikultura dalam sistem hidroponik*. Jakarta: Direktorat Jenderal Hortikultura.

Krestiani, V., & Supriyo, H. (2022). Kajian macam media tanam dan konsentrasi nutrisi AB mix terhadap pertumbuhan dan hasil tanaman selada (*Lactuca sativa* L.) pada sistem hidroponik drip irrigation. *Muria Jurnal Agroteknologi (MJ-Agroteknologi)*, ***1***(1), 22-29. https://doi.org/10.24176/mjagrotek.v1i1.8250

Krisna, B., Putra, E.E.T.S., Rogomulyo, R., & Kastono, D. (2017). Pengaruh pengayaan oksigen dan kalsium terhadap pertumbuhan akar dan hasil selada keriting (*Lactuca sativa* L.) pada hidroponik rakit apung. *Vegetalika*, ***6***(4), 14-27. https://doi.org/10.22146/veg.30900

Lingga, P. (1984). *Hidroponik: Bercocok tanam tanpa tanah*. Jakarta: Niaga Swadaya.

Lou, S.-T., Ouyang, Z.-Q., Zhang, Y., Li, X.-J., Hu, J., Li, M.-Q., & Yang, F.-J. (2000). Nanobubbles on solid surface imaged by atomic force microscopy. Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structures Processing, Measurement, and Phenomena, ***18***, 2573–2575. https://doi.org/10.1116/1.1289925

Mulatsih, S., Sarina, S., & Miftah, M. (2021). Pertumbuhan dan hasil selada keriting (*Lactuca sativa* L.) pada dataran rendah dengan pemberian dosis dan aplikasi frekuensi bokashi daun lam toro. *Jurnal Agroqua*, ***19***(2). https://doi.org/10.32663/ja.v19i2.2198

Nirmalkar, N., Paceka, A.W., & Barigou, M. (2018). Interpreting the interfacial and colloidal stability of bulk nanobubbles. *Soft Matter*, ***14***, 9643-9656. https://doi.org/10.1039/C8SM01949E

Rajaseger, G., Chan, K.L., Tan, K.Y., Ramasamy, S., Khin, M.C., Amaladoss, A., & Haribhai, P.K. (2023). Hydroponics: Current trends in sustainable crop production. *Bioinformation*, ***19***(9), 925–938. https://doi.org/10.6026/97320630019925

Saputri, A., MTS, J., & Rahayu, D. (2014). Analisis sebaran oksigen terlarut pada Sungai Raya. *Jurnal Teknologi Lingkungan Lahan Basah*, ***2***(1). https://doi.org/10.26418/jtllb.v2i1.4618

Sritontip, C., Nuon, D., Tong, R., Sritontip, P., Chidburee, A., & Thonglek, N. (2022). Effects of micro-nano bubbles and electrical conductivity of nutrient solution on the growth and yield of green oak lettuce in a hydroponic production system. *Journal of Sciense and Agricultural Technology*, ***3***(1), 16–24.

Takahashi, M. (2005). ζ Potential of microbubbles in aqueous solutions: Electrical properties of the gas−water interface. *The Journal of Physical Chemistry B*, ***109***(46), 21858–21864. https://doi.org/10.1021/jp0445270

Thichuto, S., Sritontip, P., Thonglek, V., & Sritontip, C. (2022). Effects of electrical conductivity and micro/nanobubbles in nutrient solutions of hydroponics on growth and yield of cherry tomato. *Journal of Science and Agricultural Technology*, ***3***(1), 19-36. https://doi.org/10.14456/jsat.2022.9

Wang, Y., Wang, S., Sun, J., Dai, H., Zhang, B., Xiang, W., Hu, Z., Li, P., Yang, J., & Zhang, W. (2021). Nanobubbles promote nutrient utilization and plant growth in rice by upregulating nutrient uptake genes and stimulating growth hormone production. *Science of the Total Environment*, ***800***, 149627. https://doi.org/10.1016/j.scitotenv.2021.149627

Yang, X., Gil, M.I., Yang, Q., & Tomás-Barberán, F.A. (2021). Bioactive compounds in lettuce: Highlighting the benefits to human health and impacts of preharvest and postharvest practices. *Comprehensive Reviews in Food Science and Food Safety*, ***21***(1), 4-45. https://doi.org/10.1111/1541-4337.12877