Agriculture (Poľnohospodárstvo), 71, 2025 (3): 122 − 131

DOI:10.2478/agri-2025-0011 Original article

Bio-Organic Hydroponic Cultivation of Curly Greens Leaf Lettuce (*Lactuca Sativa* var. *Crispa* 'Grand Rapids')

SARAH LOUISE S. ATULBA*, MARIE ANGELI C. ABENDAÑO

Bukidnon State University, Malaybalay City, Bukidnon, Philippines

Atulba, S. L. S. and Abendaño, M. A. C. (2025). Bio-organic hydroponic cultivation of curly greens leaf lettuce (*Lactuca sativa* var. crispa 'Grand Rapids'). *Agriculture (Poľnohospodárstvo), 71*(3), 122 – 131.

Hydroponic cultivation, a climate-smart technology that complements conventional agriculture, is increasingly recognised as a key strategy for enhancing food security, optimising resource efficiency and reducing environmental impacts. Over the years, several high-value crops, such as leafy vegetables and herbs, have been successfully grown in hydroponic systems on a commercial level, with limited exploration of their potential for healthier organic cultivation. This study has effectively described the effects of indigenous bio-organic nutrient solutions on the growth and development of curly green leaf lettuce (*Lactuca sativa* var. *crispa* 'Grand Rapids') grown under hydroponic cultivation. Five nutrient solution treatments using combinations of inorganic and bio-organic fertilisers namely, pure inorganic nutrient solution, pure vermitea, inorganic-vermitea, indigenous microorganisms (IMO)-vermitea, and fish amino acid (FAA)-vermitea were used. The pure vermitea nutrient solution showed the greatest improvements in plant growth, including plant height, number of leaves, leaf width, leaf length, shoot fresh weight, shoot dry weight, and root dry weight at harvest. The combination of vermitea with inorganic nutrient solution exhibited higher plant growth parameters compared to those grown using combinations of IMO and FAA, indicating the possible stunted growth of lettuce due to several factors, including the inhibitory effects of the abundant presence of microorganisms in a static solution culture. Our data revealed that pure vermitea organic nutrient solution promoted strong lettuce growth, comparable to plants grown with commercially available inorganic nutrient solution. This indicates that locally available organic nutrients can serve as a potentially effective nutrient solution for organic hydroponics, promoting healthier crop cultivation while being less harmful to the environment.

Key words: organic fertiliser, high value crops, soilless cultivation, nutrient solution, vermitea

Hydroponics or soilless cultivation is an innovative technique that utilises nutrient solution rather than soil in crop production. Hydroponic systems are generally classified into two main types: *(i)* solution culture, in which plant roots are suspended directly in a nutrient solution without any solid medium; and *(ii)* medium culture, which employs a solid substrate to support the roots and is categorized based on the medium used, such as sand, gravel, or rockwool (Kozai *et al*. 2019). Furthermore, hydroponic systems can operate as either static or continuous-flow systems, the latter employing mechanical pumps to facilitate nutrient circulation and minimise manual labour. Recently, SMART hydroponic technology, a system enhanced with sensors, automation, data analytics, and remote monitoring, has gained considerable attention for its ability to support optimal, efficient, and sustainable plant cultivation. Consequently, numerous automated and high-technology commercial hydroponic farms have been established

---

Sarah Louise S. Atulba (*Corresponding author), Marie Angeli C. Abendaño, Natural Sciences Department, College of Arts and Sciences, Bukidnon State University, Fortich Street, Malaybalay City, Bukidnon, Philippines, 8700. E-mail:slatulba@gmail.com; marieangeliabendano@buksu.edu.ph

worldwide, offering sustainable and profitable alternatives to conventional crop production. (Sambo *et al*. 2019; Ullah *et al*. 2019; Lakshmanan *et al*. 2020; Modu *et al*. 2020; Srinidhi *et al*. 2020).

Hydroponics is increasingly recognised as a sustainable and efficient approach to achieving food security while conserving resources and protecting the environment. It allows high-yield and high-quality crop production in limited spaces while using fewer resources and reducing environmental impacts. Compared with traditional farming, hydroponic systems require less water and pesticides and enable continuous crop production throughout the year (Kozai *et al*. 2019). Moreover, hydroponically cultivated plants often demonstrate enhanced nutritional profiles relative to soil-grown crops, primarily due to the precise control of nutrient composition and water delivery inherent in hydroponic systems. This controlled environment optimises nutrient uptake efficiency and water use, leading to improved plant metabolism and overall crop quality (Kozai *et al*. 2019).

High value crops (HVC) such as lettuce and basil are particularly well-suited for hydroponic cultivation due to their high market demand, short growth cycles and favourable net income returns under controlled environments (Malik 2021; Puccinelli *et al*. 2021). In addition to these, several other HVCs, including leafy vegetables, herbs, and fruiting crops such as tomatoes, have been successfully grown in hydroponic systems on commercial levels (Shinde & Marathe 2021; Sathyanarayana *et al*. 2022). The recent work of Puccinelli *et al*. (2021) has made great efforts to improve not only the yield but also the nutritional content of basil and lettuce plants. Malik (2021) observed the development of lettuce and basil under different hydroponic growing systems and commercial fertilisers; however, no recent studies have focused on bio-organically grown HVCs using bio-organic fertilisers as nutrient solution. At present, the demands of consumers for food are focused on the production of organic crops to improve a healthier diet and ensure safety from chemical residues of pesticides. The growing consumer preference for certified organic produce, coupled with its high market value, underscores the increasing interest in developing organic production systems that integrate hydroponic technology. Although hydroponically grown crops are produced under sterile and controlled conditions, they are not inherently organic because conventional hydroponic systems rely on inorganic nutrient solutions. This presents a critical gap in achieving truly sustainable and organic food production within controlled environments (Di Gioia & Rosskopf 2021; Di Gioia *et al*. 2021). Given the increasing global demand for safe and environmentally responsible food, there is an urgent need to develop hydroponic systems that integrate organic nutrient sources and management practices suitable for limited spaces and resource-efficient production. While a number of studies have already been conducted on growing lettuce and basil cultivars in a hydroponic system, limited information is available on the efficiency of using organic-based nutrient solutions. The commonly used organic nutrient solutions are made from vermicast and cattle or swine manure (Arancon *et al*. 2019; Churilova & Midmore 2019; Tikasz *et al*. 2019). At present, indigenous microorganisms (IMO) and fish amino acid (FAA) are increasingly recognised as potential organic fertilisers for hydroponic systems, providing sustainable alternatives to conventional inorganic nutrient sources. Derived from natural biological processes through microbial fermentation, these inputs supply essential nutrients and bioactive compounds that support plant growth (Vessey 2003). IMO enhances nutrient cycling and microbial activity within the growing medium (Illani Zuraihah *et al.* 2012; Kumar & Gopal 2015), while FAA provides readily available amino acids, peptides, and trace minerals that stimulate plant metabolism and nutrient uptake (Uma & Jeevan 2022; Bhuimbar & Dandge 2023).

Despite their widespread use in conventional organic farming, the combined application of IMO and FAA with vermicast as components of bio-organic liquid fertilisers for hydroponic cultivation remains largely unexplored. Moreover, locally produced bio-organic fertiliserswhich are readily available in the province, lack research-based information on their effectiveness despite being widely used in local farms. Therefore, this study aims to: *(i)* determine the chemical composition of the bio-organic nutrient solutions; *(ii)* compare the growth and development of leaf lettuce as affected by different bio-organic nutrient solutions and inorganic nutrient solutions, and *(iii)* create a recommendation for the optimum organic nutrient solution formulation for hydroponic cultivation.

MATERIAL AND METHODS

The study was conducted in a greenhouse located at Barangay Casisang, Malaybalay City, Bukidnon. Plants were grown under natural lighting conditions using dechlorinated water as the base medium for the preparation of nutrient solutions. The experiment lasted for 70 days, encompassing the entire growth period from set-up and sowing to harvesting. Hydroponic cultivation was carried out using the Kratky method, employing styroboxes with dimensions of 35 × 17 × 7.5 inches, each containing 15 planting holes to accommodate individual plants. The experiment was laid out in a completely randomised design (CRD) with five treatments and 15 replicates per treatment. Each replicate represented an individual test plant grown under uniform environmental conditions to minimise variability.

Nutrient Solution Preparation

The nutrient solution for hydroponic cultivation of crops was custom-formulated using combinations of inorganic and bio-organic nutrient solution sources such as vermicast tea (vermitea), IMO, and FAA at different ratios.

In this study, the inorganic nutrient solution served as the positive control, providing a standard, well-established nutrient baseline against which the effects of the bioorganic nutrient treatments could be compared. The inorganic nutrient solution used in the experiment was commercially obtained and consisted of two concentrated stock solutions: Solution A (9 – 0 – 0), referred to as the *Grow solution*, and Solution B (0 – 5 – 7), referred to as the *Bloom solution*. These nutrient concentrates were diluted with tap water naturally dechlorinated by 24-hour exposure to sunlight and open air, following the recommended mixing ratio of 1.0 mL/1.5 L to prepare the working nutrient solution.

The organic nutrient solution was prepared at a concentration of 10% (w/v) by mixing 5 kg of vermicast with 50 L of dechlorinated water. The vermicast was enclosed in porous bags, tightly sealed, and submerged in the dechlorinated water under aerobic conditions for approximately 12 – 24 hours, or until the extract developed a light brown colouration, indicating nutrient leaching. The resulting filtrate, referred to as vermitea, was then collected and utilised as the organic hydroponic nutrient solution for the cultivation of high-value crops. The organic nutrient solution (vermitea) was analysed for its nutrient contents. Analyses were as follows: total nitrogen (total N) (Kjeldahl method), total phosphorus (total P) (4500-P D. Stannous Chloride Method), potassium (K) and sodium (Na) (3030 F. Nitric Acid-Hydrochloric Acid Digestion, 3111 B. Direct Air-Acetylene Flame AES), calcium (Ca) and magnesium (Mg) (3030 F. Nitric Acid Hydrochloric Acid Digestion, 3111 B. Direct Air-Acetylene Flame AAS). Table 1 exhibits the chemical composition and concentrations of vermitea. The custom-formulated base organic solution of vermitea demonstrates a substantial presence of macronutrients essential for facilitating plant growth. Thus, it is deemed suitable for utilisation as the foundational nutrient solution in organic hydroponic cultivation practices.

Plant Cultivation (Germination and Transplanting)

Curly green leaf lettuce (*Lactuca sativa* var. *crispa* 'Grand Rapids') seeds were sown in rockwool germination trays and irrigated with tap water for 15 days under natural light at room temperature (RT). After 15 days, when the plants developed 3 – 4 leaves, the lettuce seedlings were transplanted to the hydroponic system and grown hydroponically for 35 days. The plants were fed with nutrient solutions manually each week. The pH and electrical conductivity (EC) of the nutrient solutions were regularly

Table 1

Chemical composition of pure vermitea base organic solution before combining with chemical and bio-organic fertilisers

Nutrients	Concentration [mg/L]
Total N	11.30
Total P	6.90
K	106.00
Na	14.00
Ca	221.00
Mg	70.10

checked using calibrated pH and EC meters to ensure optimal nutrient availability. The EC was maintained at 1.5 dS/m by adding dechlorinated water as needed to compensate for losses from evaporation and transpiration, thereby maintaining the desired nutrient balance and preventing an increase in EC due to solution concentration. The following treatments were applied to the leaf lettuce during hydroponic cultivation:

T1 – Inorganic nutrient solution

T2 – Vermitea

T3 – Inorganic nutrient solution (50% v/v) + vermitea (50% v/v)

T4 – Vermitea with IMO (1% v/v)

T5 – Vermitea with FAA (1% v/v)

The T1 treatment consisted of a commercially prepared inorganic nutrient solution, while T2 utilised an organic nutrient solution derived from vermicast. The T3 treatment combined the inorganic and organic nutrient solutions in equal proportions (50% v/v), whereas T4 and T5 were formulated by enriching vermitea with 1% (v/v) IMO and FAA, respectively.

Plant Measurement and Sampling

Plant growth parameters were measured once every 5 days during the 35-day plant cultivation. At the end of the 35-day cultivation period, plants were harvested and separated into shoots and roots. The parameters measured included shoot fresh weight, root fresh weight, shoot dry weight, and root dry weight**.** Fresh weights were recorded immediately after harvest using a top-loading balance, while dry weights were obtained after oven-drying the samples at 60°C for five days until a constant weight was achieved and dry weights of the shoots and roots.

Data Gathering and Analysis

The collected data of measured plant parameters were utilised in understanding the growth performances of lettuce in response to the organic hydroponic growing system. Data were analysed using analysis of variance (ANOVA) under a completely randomised design (CRD). Treatment means were compared using Tukey's honest significant difference (HSD) test at a 5% level of significance ($p < 0.05$) to ensure statistically valid pairwise comparisons among treatments.

RESULTS

The plant height of curly green leaf lettuce was significantly different among the five treatments across the entire plant cultivation period (Figure 1). Lettuce plants treated with vermitea (T2) exhibited the highest plant height among all treatments. At 28 days after transplanting (DAT), plant height was observed to be higher in plants treated with vermitea (T2) and those treated with a combination of vermitea and inorganic nutrient solution (T3). This finding aligns with the study conducted by Musa *et al.* (2018), which demonstrated that applying various concentrations of vermitea increased the plant height of hydroponically grown spinach. In contrast, the plant heights of chemically grown lettuce (T1) and those treated with bioorganic fertilisers (T4 and T5) were significantly lower than those of lettuce plants grown using vermitea treatments (T2 and T3). This result highlights the superior efficacy of vermitea in promoting the growth of hydroponically grown lettuce compared to commercially produced inorganic nutrient solutions.

Figure 2 presents the leaf-specific growth parameters of curly green leaf lettuce, including the number of leaves, leaf width, and leaf length, measured at various growth stages under different nutrient solution treatments. The number of leaves of lettuce plants varied across treatments throughout the entire cultivation period. Lettuce plants grown under pure vermitea (T2) and the combination of vermitea with inorganic nutrient solution (T3) exhibited the highest number of leaves. The values observed in these treatments were not significantly different from those obtained in plants treated with inorganic nutrient solution alone (T1), suggesting that vermitea has a comparable effect to inorganic nutrient solution in promoting leaf development. These findings align with previous studies demonstrating an increase in the number of leaves in hydroponically grown spinach following the application of different concentrations of vermitea (Musa *et al.* 2018). Conversely, at 28 days after transplanting (DAT), lettuce plants grown under vermitea treatments with IMO and FAA (T4 and T5) displayed a lower number of leaves compared to plants treated with and vermitea-based solutions. This result highlights the effectiveness of vermitea solutions in enhancing leaf production in lettuce. Leaf width showed highly significant differences among treatments throughout the entire growth period. The highest leaf widths were observed in lettuce plants grown under pure vermitea solution (T2) at all stages of cultivation. At 28 DAT, plants treated with pure vermitea (T2) and the combination of vermitea and inorganic nutrient solution (T3) had greater leaf widths compared to those under other treatments. In contrast, plants treated with bioorganic fertilisers (T4 and T5) exhibited smaller leaf widths, while those treated with inorganic nutrient solution alone (T1) showed remarkably lower leaf widths. These findings suggest that the presence of vermitea in the nutrient solution substantially enhanced leaf width in lettuce plants. Similar results have been reported in previous studies, where the application of vermitea led to improved plant parameters such as leaf area, number of leaves, and plant height in spinach (Musa *et al.* 2018).

Leaf length also exhibited significant differences among treatments across different growth stages. Lettuce plants treated with pure vermitea (T2) consistently displayed the longest leaf lengths throughout cultivation. At 28 DAT, the leaf length of plants under pure vermitea (T2) was not significantly different from that of plants grown using inorganic nutrient solution (T1) to indicate that the effect of pure vermitea is comparable to that of inorganic nutrient solution in enhancing the leaf length of lettuce plants. Additionally, the combination of inorganic nutrient solution and vermitea (T3) resulted in enhanced leaf length at 28 DAT. However, plants grown with bioorganic fertilisers (T4 and T5) produced the shortest leaves, with those treated with FAA (T5) exhibiting the lowest values. This outcome aligns with previous research suggesting that nutrient solutions derived from fish waste require further refinement to optimise lettuce growth (Ahmed *et al*. 2021).

Figure 3 presents the fresh and dry weight of curly green leaf lettuce (roots and shoots) measured at 28 DAT under different nutrient solution treatments. Shoot and root fresh weights of lettuce were significantly different among treatments. The highest shoot fresh weight was observed in plants grown using pure vermitea (T2), although it was not significantly different from those grown with a combination of vermitea and inorganic nutrient solution (T3). This finding contrasts with the results reported by Churilova and Midmore (2019), which suggest that different nutrient formulations may influence biomass accumulation differently. The application of (FAA) as a bioorganic fertiliser (T5) resulted in the lowest shoot fresh weight, indicating that FAA amendment does not effectively enhance biomass accumulation in hydroponically grown leaf lettuce.

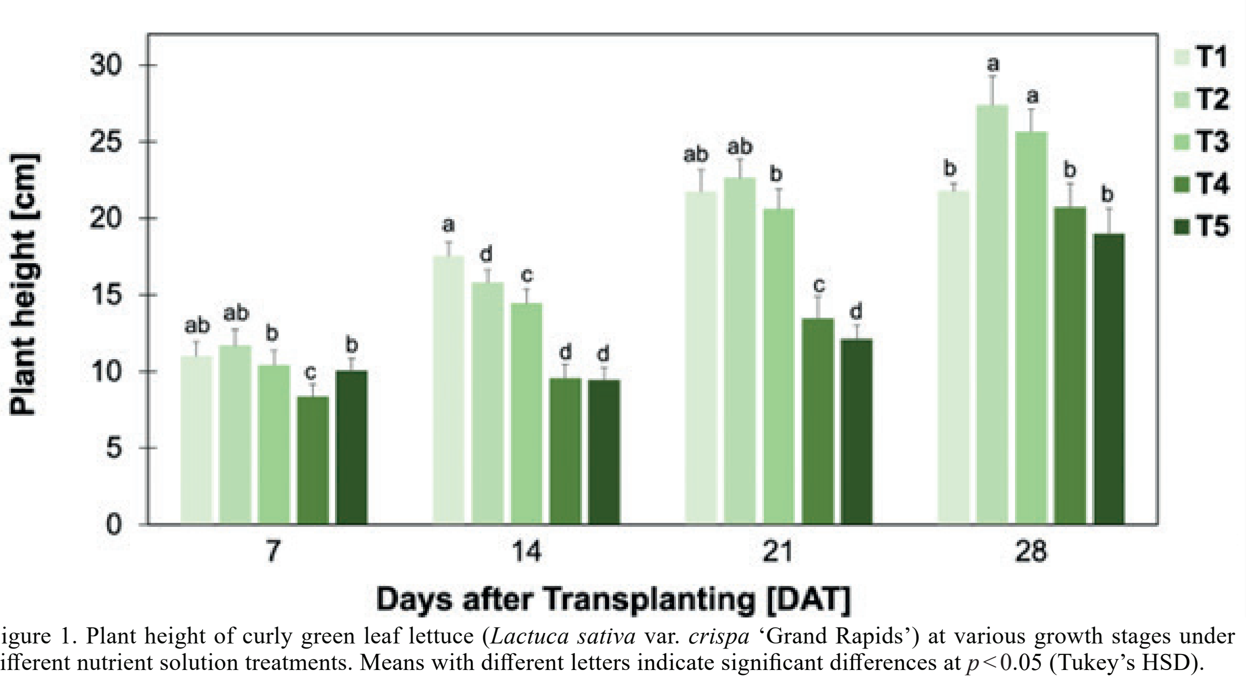

Figure 1. Plant height of curly green leaf lettuce (*Lactuca sativa* var. *crispa* 'Grand Rapids') at various growth stages under different nutrient solution treatments. Means with different letters indicate significant differences at $p < 0.05$ (Tukey's HSD). Note: HSD – honest significant difference.

Root fresh weight was observed to be highest in plants treated with IMO (T4), although it was not significantly greater than that of plants treated with pure vermitea (T2) and the combination of vermitea and inorganic nutrient solution (T3). The presence of IMO in the nutrient solution likely stimulated root development, leading to increased root fresh weight. However, lettuce plants treated with inorganic nutrient solution (T1) exhibited lower root fresh weight compared to bioorganic fertiliser treatments, suggesting that IMO and other organic amendments promote better root biomass development than inor-

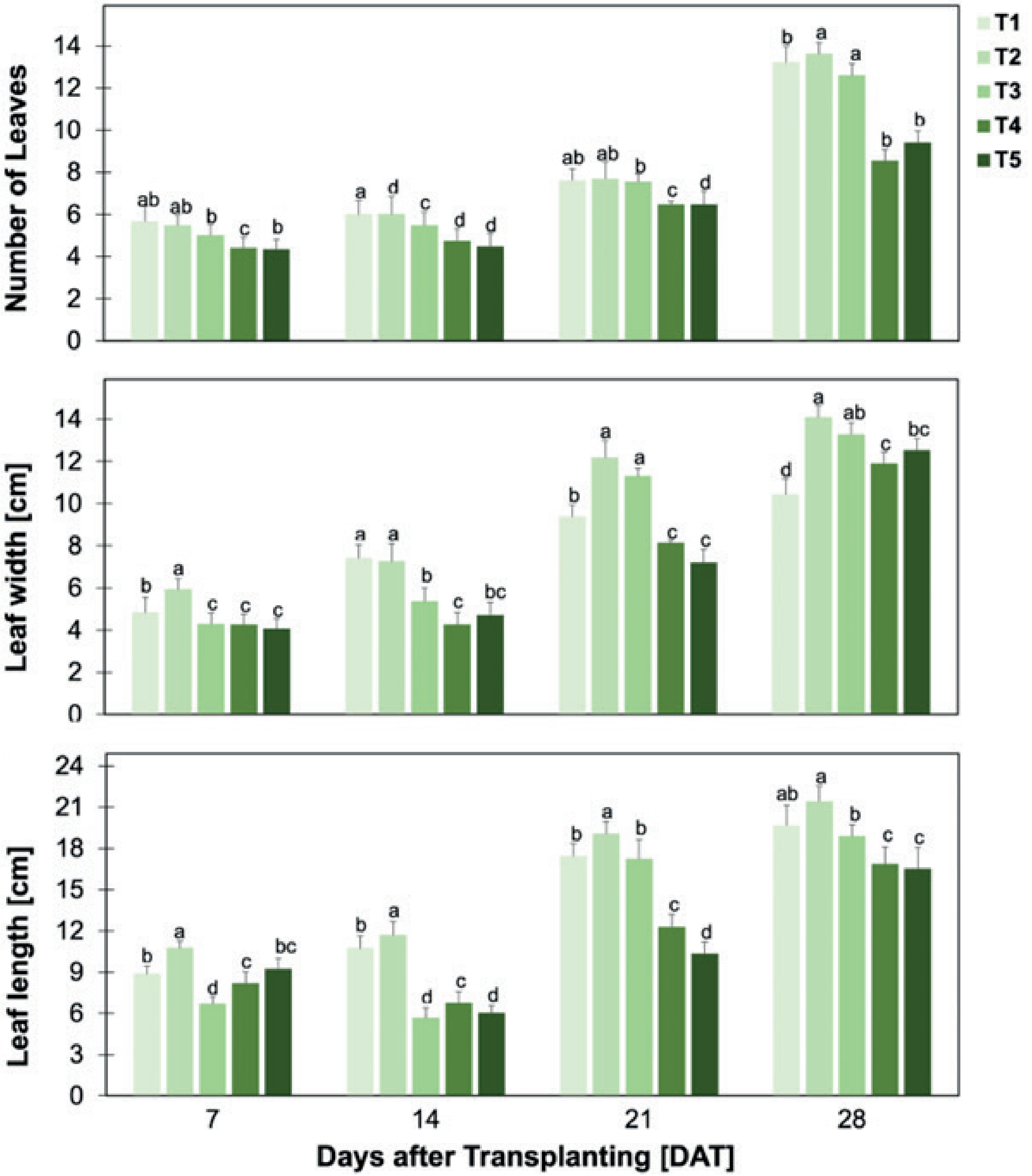

Figure 2. Leaf-specificgrowth parameters of curly green leaf lettuce (*Lactuca sativa* var. *crispa* 'Grand Rapids') (number of leaves, leaf width, and leaf length) measured at various growth stages under different nutrient solution treatments. Means with different letters indicate significant differences at $p < 0.05$ (Tukey's HSD).
Note: HSD – see Figure 1.

ganic fertilisers. Figure 3 also presents the shoot and root dry weights of lettuce at 28 DAT. The highest shoot dry weight was recorded in lettuce grown under pure vermitea treatment (T2), which aligns with the highest shoot fresh weight observed in the same treatment. Root dry weight, on the other hand, was equally highest among plants grown under pure vermitea (T2) and the combination of vermitea and inorganic nutrient solution (T3). Interestingly, despite having the highest root fresh weight, the IMO treatment (T4) exhibited a 13.5% lower root dry weight compared to T2 and T3. This suggests that the increased root fresh weight observed in plants under T4 was largely due to higher water content rather than actual plant biomass accumulation.

DISCUSSION

The significant increase in plant height observed in vermitea-treated lettuce plants (T2) suggests that vermitea provides essential nutrients and growth-promoting substances that enhance vegetative development (Figure 1). Vermitea may contain plant growth hormones leading to enhanced plant height (Arancon *et al.* 2004). Additionally, vermitea

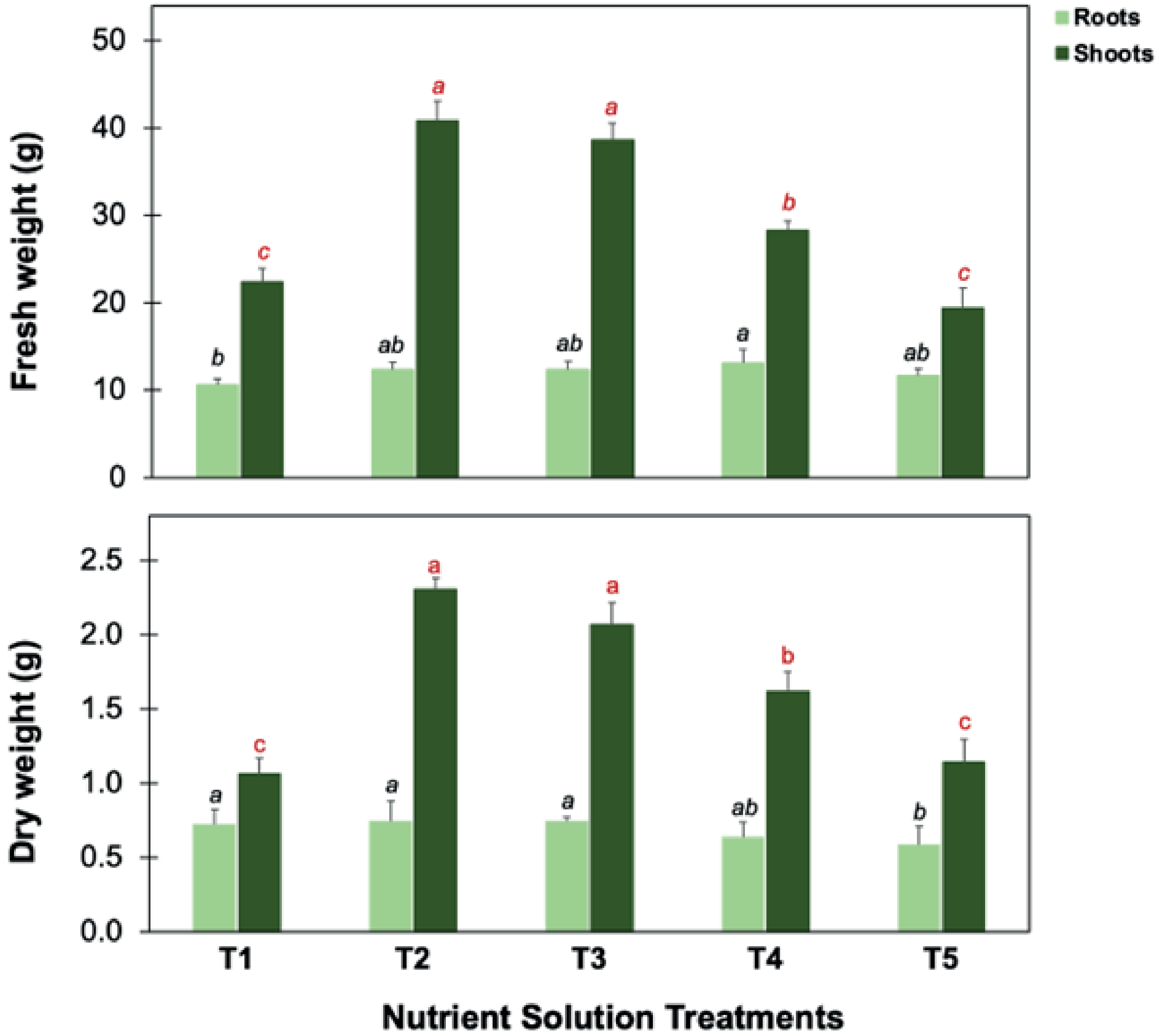

Figure 3. Fresh and dry weight of curly green leaf lettuce (*Lactuca sativa* var. *crispa* 'Grand Rapids') (roots and shoots) measured at 28 days after transplanting under different nutrient solution treatments. Means with different letters indicate significant differences at $p < 0.05$ (Tukey's HSD).
Note: HSD – see Figure 1. Letters shown in red denote significant differences specifically for shoot weight.

improves nutrient bioavailability and microbial activity in the root zone, which further supports plant growth (Pant *et al*. 2009; Pant *et al*. 2011). The combination of vermitea and inorganic nutrient solution (T3) also resulted in increased plant height, possibly due to the synergistic effects of organic and inorganic nutrient sources, which optimise nutrient uptake efficiency (Edwards *et al*. 2006). The reduced plant height in lettuce treated with inorganic nutrient solution (T1) and bioorganic fertilisers (T4 and T5) may be attributed to several factors. In the case of bioorganic fertilisers, while they are designed to enhance soil fertility by introducing beneficial microorganisms, an excessive microbial population can lead to unintended consequences. High microbial activity can increase competition for oxygen in the rhizosphere, potentially creating anaerobic conditions detrimental to plant roots. Beneficial bacteria and fungi that promote plant growth typically require aerobic conditions, and when oxygen levels drop, these microorganisms become less effective, and harmful pathogens may proliferate. Furthermore, the decomposition of organic matter by these microorganisms can lead to the production of phytotoxic substances or the immobilisation of essential nutrients, making them less available to plants (Fageria & Stone 2006). This indicates that microbial activity can alter soil nutrient dynamics, sometimes in ways that are not beneficial to plant growth.

In contrast, vermitea treatments (T2 and T3) not only supply essential nutrients but also introduce a balanced microbial community that enhances nutrient availability without overwhelming the oxygen balance in the hydroponic solution. This balance may have supported optimal root function and overall plant growth. These findings underscore the importance of managing the controlled environments of microbial communities in bioorganic fertilisers to prevent potential negative impacts on plant growth. Future research should focus on optimising the composition and application rates of bioorganic fertilisers to harness their benefits while mitigating risks associated with excessive microbial activity. While inorganic nutrient solution supplies essential macronutrients, they may not enhance root microbiota activity or provide secondary metabolites that promote growth as effectively as vermitea (Fageria & Stone 2006; Canellas *et al*. 2015). Similarly, bioorganic fertilisers may have released nutrients more slowly, limiting immediate nutrient uptake compared to the more readily available nutrients in vermitea treatments. These findings emphasise the potential of vermitea as an effective organic alternative to conventional inorganic nutrient solutions for enhancing the growth of hydroponically grown lettuce. Future studies should explore the long-term effects of vermitea on other growth parameters, yield, and nutrient composition of lettuce under hydroponic conditions. The results indicate that vermitea, either as a stand-alone nutrient source or in combination with inorganic nutrient solution, plays a significant role in improving the leaf-specific growth parameters of curly green leaf lettuce (Figure 2). The comparable performance of pure vermitea (T2) and inorganic nutrient solution (T1) in terms of leaf number, leaf width, and leaf length suggests that vermitea is a viable alternative to conventional inorganic fertilisers. This supports previous findings that highlight the beneficial effects of vermitea in enhancing plant growth parameters, including leaf development and biomass accumulation (Musa *et al*. 2018). The increased leaf width and length observed in vermitea-treated plants may be attributed to the presence of essential nutrients and microbial activity that improve nutrient uptake and plant metabolism. Vermitea contains beneficial microorganisms and bioavailable nutrients that enhance plant growth (Edwards *et al*. 2010). The improvement in leaf size parameters aligns with the theory that organic fertilisers can promote plant vigour by increasing chlorophyll content and enhancing enzymatic activities that facilitate photosynthesis (Pant *et al*. 2011). On the other hand, the relatively lower leaf growth performance observed in plants treated with bioorganic fertilisers (T4 and T5) suggests that these fertilisers may have slower nutrient release rates or lower nutrient bioavailability compared to vermitea and inorganic nutrient solution. This is consistent with previous research indicating that fish-based organic fertilisers require further optimization to enhance nutrient availability for plant uptake (Ahmed *et al*. 2021). The reduced growth observed in these treatments underscores the importance of refining organic nutrient solutions to match the rapid growth demands of lettuce, particularly in hydroponic or controlled environment systems. The results shown in Figure 3 indicate that vermitea, whether used alone or in combination with inorganic nutrient solution, is an effective nutrient solution for improving both shoot and root biomass in hydroponically grown curly green leaf lettuce. The comparable performance of pure vermitea (T2) and the combination of vermitea and (T3) in terms of shoot fresh and dry weight suggests that vermitea provides essential nutrients that support shoot growth, potentially replacing or supplementing inorganic nutrient solutions. These findings align with previous studies highlighting the beneficial effects of vermitea in enhancing plant growth parameters, including biomass accumulation and root development (Pant *et al*. 2009; Pant *et al*. 2011). The increased root fresh weight observed in IMO-treated plants (T4) suggests that indigenous microorganisms contribute to root growth stimulation. However, the lower root dry weight in T4 compared to T2 and T3 implies that the observed increase in root mass was primarily due to higher water retention rather than actual biomass formation. This finding is consistent with prior research suggesting that IMO enhances soil microbial activity and water retention but may require additional nutrient supplementation to optimise plant biomass production (Churilova & Midmore 2019). The relatively lower shoot fresh and dry weights in plants treated with FAA (T5) indicate that fish amino acid-based fertilisers may not be as effective in promoting biomass accumulation in lettuce. Previous research suggests that FAA may have variable effects depending on nutrient composition and application rates (Ahmed *et al*. 2021). Further refinement of fish-based organic fertilisers is necessary to enhance their efficacy in hydroponic lettuce cultivation. Overall, the study underscores the potential of vermitea as an alternative nutrient solution for optimising the fresh and dry biomass of lettuce, particularly in hydroponic systems. Future studies should investigate the long-term effects of vermitea and IMO on plant growth, yield quality, and nutrient use efficiency to further validate their application in sustainable agriculture.

CONCLUSIONS

This study has successfully grown curly green leaf lettuce under hydroponic cultivation using bioorganic fertilisers as nutrient solutions. The custom-formulated base organic solution of vermitea contains considerable amounts of macronutrients needed for plant growth and development. Throughout the entire hydroponic cultivation of curly green leaf lettuce, pure vermitea (T2) remarkably increased the growth of leaf lettuce in terms of plant height, number of leaves, leaf width, leaf length, shoot fresh weight, shoot dry weight, and root dry weight. Lettuce grown using inorganic nutrient solution and vermitea (T1-T3) showed better plant growth compared to those that were grown using bioorganic nutrient solution amended with IMO and FAA (T4 and T5). Lettuce grown organically with pure vermicompost showed remarkably higher growth improvement compared to lettuce plants grown using an inorganic nutrient solution. Therefore, this study recommends the use of pure vermitea for hydroponic cultivation as it enhances the growth and development of organically produced lettuce while promoting environmental sustainability.

Acknowledgement: This study was funded by Bukidnon State University through the Research Unit, with additional support from the BukSU Science Laboratory. The authors gratefully acknowledge the technical and administrative assistance of the University that contributed to the successful completion of this research.

REFERENCES

Ahmed, Z., Alnuaimi, A., Askri, A., and Tzortzakis, N. (2021). Evaluation of lettuce (*Lactuca sativa* L.) production under hydroponic system: Nutrient solution derived from fish waste vs. inorganic nutrient solution. *Horticulturae*, 7(9), 292. DOI:10.3390/horticulturae7090292.

Arancon, N., Owens, J. and Converse, C. (2019). The effects of vermicompost tea on the growth and yield of lettuce and tomato in a non-circulating hydroponics system. *Journal of Plant Nutrition*, *42,* 2447 – 2458. DOI:10.1080/01904167.2019.1655049.

Arancon, N., Edwards, C., Bierman, P., Metzger, J., Lucht, C., and Blair, J. (2004). Effects of vermicomposts on growth and marketable fruits of field-grown tomatoes, peppers, and strawberries. *Pedobiologia*, *47*(5 – 6), 731 – 735. DOI:10.1016/S0031-4056(04)70216-0.

Bhuimbar, M.V. and Dandge, P.B. (2023). Production of organic liquid biofertilizer from fish waste and study of its plant growth promoting effect. *Proceeding of the National Academy of Sciences, India, Section B: Biological Sciences, 93,* 235 – 243. DOI:10.1007/s40011-022-01413-8.

Canellas, L.P., Olivares, F.L., Aguiar, N.O., Jones, D.L., Nebbioso, A., Mazzei, P., and Piccolo, A. (2015). Humic and fulvic acids as biostimulants in horticulture. *Scientia Horticulturae*, *196,* 15 – 27. DOI:10.1016/j.scienta.2015.09.013.

Churilova, E. and Midmore, D. (2019). Vermiliquer (Vermicompost Leachate) as a complete liquid fertilizer for hydroponically-grown pak choi (Brassica chinensis L.) in the tropics. *Horticulturae*, *5*(1), 26. DOI:10.3390/horticulturae5010026.

Di Gioia, F., Petropoulos, S., Ferreira, I., and Rosskopf, E. (2021). Microgreens: From trendy vegetables to functional food and potential nutrition security resource. *ISHS Acta Horticultura: III International Symposium on Soilless Culture and Hydroponics: Innovation and Advanced Technology for Circular Horticulture*, 1321, 235 – 242. DOI:10.17660/ActaHortic.2021.1321.31.

Di Gioia, F. and Rosskopf, E.N. (2021). Organic hydroponics: A US reality challenging the traditional concept of "organic" and "soilless" cultivation. *ISHS Acta Horticulturae: III International Symposium on Soilless Culture and Hydroponics: Innovation and Advanced Technology for Circular Horticulture*, 1321, 275 – 282. DOI:10.17660/ActaHortic.2021.1321.36.

Edwards, C., Arancon, N. and Greytak, S. (2006). Effects of vermicompost teas on plant growth and disease. *Biocycle*, *47*(5), 28.

Fageria, N.K. and Stone, L.F. (2006). Physical, chemical, and biological changes in the rhizosphere and nutrient availability. *Journal of PlantNutrition*, *29*(7), 1327 – 1356. DOI:10.1080/01904160600767682.

Illani Zuraihah, I., Aini, Z. and Faridah M. (2012). Effects of IMO and EM application on soil nutrients, microbial population and crop yield. *Journal of Tropical Agriculture and Food Science*, *40*(2), 257 – 263.

Kozai, T., Niu, G. and Takagaki, M. (2019). *Plant Factory: an Indoor Vertical Farming System for Efficient Quality Food Production*, 2nd ed. Academic press, 516p.

Kumar, B.L. and Gopal, D.S. (2015). Effective role of indigenous microorganisms for sustainable environment. *3 Biotech*, *5*(6), 867 – 876. DOI:10.1007/s13205-015-0293-6.

Lakshmanan, R., Djama, M., Selvaperumal, S., and Abdulla, R. (2020). Automated smart hydroponics system using internet of things. *International Journal of Electrical and Computer Engineering*, *10*(6), 6389 – 6398. DOI:10.11591/ijece.v10i6.pp6389-6398.

Malik, O. (2021). *Urban Farming: Production Comparison of Basil and Oak Leaf lettuce in Two Hydroponic Growing Systems*. Available at: https://core.ac.uk/reader/395091930 [Accessed Feb. 15, 2025].

Modu, F., Adam, A., Aliyu F., Mabu, A., and Musa, M. (2020). A survey of smart hydroponic systems. *Advances in Science, Technology and Engineering Systems Journal*, *5*(1), 233 – 248. DOI:10.25046/aj050130.

Musa, S., Njoku, L. and Ndiribe, C. (2018). The effect of vermi tea on the growth parameters of *Spinacia oleracea* L. (Spinach). *Journal of Environmental Science and Pollution Research*, *3*(4), 236 – 238. DOI:10.13140/RG.2.2.25268.71041.

Pant, A., Radovich, T., Hue, N., Talcott, S., and Krenek, K. (2009). Vermicompost extracts influence growth, mineral nutrients, phytonutrients and antioxidant activity in pak choi (Brassica rapa cv. Bonsai, Chinensis group) grown under vermicompost and chemical fertiliser. *Journal of the Science of Food and Agriculture*, *89*(14), 2383 – 2392. DOI:10.1002/jsfa.3732.

Pant, A., Radovich, T., Hue, N., and Arancon, N. (2011). Effects of vermicompost tea (Aqueous Extract) on pak choi yield, quality, and on soil biological properties. *Compost Science & Utilization, 19*(4), 279 – 292. DOI:10.1080/1065657X.2011.10737010.

Puccinelli, M., Landi, M., Maggini, R., Pardossi, A., and Incrocci, L. (2021). Iodine biofortification of sweet basil and lettuce grown in two hydroponic systems. *Scientia Horticulturae*, *276,* 109783. DOI:10.1016/j.scienta.2020.109783

Sambo, P., Nicoletto, C., Giro, A., Pii, Y., Valentinuzzi, F., Mimmo, T., Lugli, P., Orzes, G., Mazzetto F., and Astolfi, S. (2019). Hydroponic solutions for soilless production systems: issues and opportunities in a smart agriculture perspective. *Frontiers in Plant Science*, *10,* 923. DOI:10.3389/fpls.2019.00923.

Sathyanarayana, S., Gangadhar, W., Badrinath, M., Ravindra, R., and Shriramrao, A. (2022). Hydroponics: an intensified agriculture practice to improve food production. *Reviews in Agricultural Science*, *10,* 101 – 114. DOI:10.7831/ras.10.0_101.

Shinde, C. and Marathe, P. (2021). Farming without soil in today's era. *Iconic Research and Engineering Journals*, *4*(7), 24 – 27.

Srinidhi, H., Shreenidhi, H. and Vishnu, G. (2020). Smart hydroponics system integrating with IoT and machine learning algorithm. In *2020 International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT)*, pp. 261 – 264. IEEE.

Tikasz, P., MacPherson, S., Adamchuk, V., and Lefsrud, M. (2019). Aerated chicken, cow, and turkey manure extracts differentially affect lettuce and kale yield in hydroponics. *International Journal of Recycling of Organic Waste in Agriculture*, *8,* 241 – 252. DOI:10.1007/s40093-019-0261-y.

Ullah, A., Aktar, S., Sutar, N., Kabir, R., and Hossain, A. (2019). Cost effective smart hydroponic monitoring and controlling system using IoT. *Intelligent Control and Automation*, *10*(4), 142 – 154. DOI:10.4236/ica.2019.104010.

Uma, S. and Jeevan, P. (2022). Production of organic manure "FAA" – Fish amino acid. In Yogananth, N., Sheeba, E., Sivakumar, T., Bhakyaraj, R. (Eds.) *Bioentrepreneurship in Biosciences: Recent approaches*, 1st ed. Tamil Nadu, India: Darshan Publishers, pp. 119–134. Avaiable at: https://books.google.com.ph/books?hl=en&lr=&id=6ht1EAAAQBAJ&oi=fnd&pg=PA119.

Vessey, J.K. (2003). Plant growth promoting rhizobacteria as biofertilizers. *Plant and Soil, 255,* 571 – 586. DOI:10.1023/A:1026037216893.

Received: April 14, 2025
Accepted: November 26, 2025