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Effectiveness of Fish Amino Acid Organic Fertilizer on the Growth Performance of Lettuce (*Lactuca sativa*) under Vertical Farming System

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Abstract: The increasing demand for leafy vegetables in urban areas has emphasized the need for sustainable and space-efficient farming practices. This study investigates the effects of organic Fish Amino Acid (FAA) fertilizer on the growth of lettuce (*Lactuca sativa*) using a vertical farming (VF) system. Lettuce seedlings were treated with varying concentrations of FAA fertilizer: 0 mL (control), 25.5 mL, 30.5 mL, and 35.5 mL per application. Growth parameters, including plant height and leaf count, were recorded over five weeks. The FAA was prepared via fermentation of catfish (Clarias spp.) waste with molasses. Results showed that lettuce treated with 30.5 mL FAA exhibited optimal growth with significant increases in height and leaf number compared to other treatments. The study concludes that FAA at 30.5 mL is a promising alternative to chemical fertilizers in enhancing lettuce growth under limited-space cultivation like VF systems.

Keywords: Fish amino acid, vertical farming, organic fertilizer, Lactuca sativa, urban agriculture

1. Introduction

Urban agriculture has garnered increasing attention in Malaysia in recent years, driven by the urgent need to enhance food security, reduce dependency on food imports, and promote sustainable urban living (Aziz et al., 2021; Kamaruddin et al., 2020). In response to global food system vulnerabilities and rising living costs, the Malaysian government has introduced various urban agriculture initiatives, including Pertanian Bandar programs aimed at empowering local communities to grow their own food. These efforts have significantly increased public awareness and participation in urban farming, particularly in major cities such as Kuala Lumpur and Putrajaya, where the number of urban farmers has grown substantially (Ministry of Agriculture and Food Industries Malaysia, 2022).

One of the most innovative approaches within this domain is vertical farming (VF), a modern agricultural technique that addresses space limitations by growing crops in vertically stacked layers within controlled indoor environments. Vertical farms maximize space utilization, reduce land use pressure, and allow year-round production with minimal pesticide input (Despommier, 2013; Al-Kodmany, 2018). In Malaysia, commercial entities such as Agroz Group have pioneered vertical farming technologies by developing indoor smart farms that aim to deliver clean, pesticide-free produce while simultaneously serving as educational platforms for agricultural innovation (Agroz Group, 2023).

Lettuce (*Lactuca sativa*), a fast-growing and nutrient-rich leafy vegetable, is particularly well-suited for vertical farming due to its short production cycle, compact size, and adaptability to hydroponic systems. Its high content of vitamin A, vitamin K, and antioxidants has made it a common component in healthy diets and wellness-focused lifestyles (Bartha et al., 2015). However, optimizing lettuce production in VF systems requires the careful management of nutrient solutions, as growth, quality, and yield are highly dependent on the composition and availability of essential macro- and micronutrients (Savvas & Gruda, 2018).

While conventional hydroponic cultivation typically relies on synthetic nutrient solutions, the long-term environmental implications including eutrophication, groundwater contamination, and reduced soil fertility have prompted interest in sustainable alternatives. Among the promising organic inputs is Fish Amino Acid (FAA), a liquid organic fertilizer produced via fermentation of fish waste with carbohydrate sources such as molasses or jaggery. FAA is rich in bioavailable amino acids, peptides, vitamins, enzymes, and trace elements that are beneficial for plant physiological processes, including nitrogen assimilation, chlorophyll synthesis, and stress tolerance (Kim et al., 2014;

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Wahyuni et al., 2021). Its use also contributes to the circular economy by recycling fishery waste into valuable agricultural inputs.

Recent studies have reported the effectiveness of FAA in enhancing plant performance across various crops. For instance, in green gram (*Vigna radiata*), FAA application has been found to significantly improve seed germination, root and shoot length, and total biomass compared to untreated controls (Patil et al., 2020). FAA has also been associated with enhanced microbial activity in the rhizosphere and improved nutrient solubilization, thus promoting healthier and more resilient plant development (Nguyen et al., 2019). In the context of lettuce cultivation, the use of organic nutrient solutions derived from fish waste in hydroponic systems has shown promising results. Although some studies indicate that biomass accumulation under organic regimes may be slightly lower than conventional chemical fertilizers, the trade-off is justified by the long-term sustainability and reduced ecological footprint of organic approaches (Zhao et al., 2021; Mahmud et al., 2023).

Despite the promising benefits of FAA, there is limited research on its application in VF systems, particularly concerning lettuce cultivation. This study aims to evaluate the effectiveness of different FAA concentrations on the growth performance of lettuce in a vertical farming setup. By exploring the potential of FAA as an organic fertilizer in VF systems, this research seeks to contribute to sustainable urban agriculture practices and inform future nutrient management strategies.

2. Materials and Methods

2.1 Study Site and Duration

The experiment was conducted in November 2024 at the Horticulture Unit, Kolej Vokasional (Pertanian), Teluk Intan, Perak, Malaysia. The site was selected for its suitability in implementing a small-scale vertical farming (VF) system under semi-controlled environmental conditions typical of tropical lowland agriculture.

2.2 Preparation of Fish Amino Acid (FAA) Fertilizer

Fish Amino Acid (FAA) was prepared using a fermentation method involving 1 kg of catfish (*Clarias gariepinus*) waste, including internal organs, flesh, and bones, combined with 1 liter of molasses. The ingredients were thoroughly mixed and placed into a clean plastic container covered with breathable cloth and secured with string. The mixture was stored in a shaded, well-ventilated area to undergo anaerobic fermentation for a period of three weeks. The resulting liquid fertilizer was then filtered and stored for application.

2.3 Planting System and Seedling Preparation

Lettuce (*Lactuca sativa*) seeds were germinated in seed trays filled with a mixture of peat moss and cocopeat. After two weeks of germination, uniform seedlings were transplanted into a vertical farming structure composed of four horizontal troughs (palung), each with 20 planting holes, accommodating a total of 80 plants. The planting system utilized a passive gravity-fed irrigation system and incorporated cocopeat and peat moss as growth media.

2.4 Experimental Design

The experimental design employed a completely randomized design (CRD) with four treatment groups, each consisting of 20 replicate plants (n = 20 per treatment). The treatments were based on different FAA concentrations:

- T1: 0 mL FAA (Control)
- T2: 25.5 mL FAA
- T3: 30.5 mL FAA
- T4: 35.5 mL FAA

FAA solution was diluted in water to the required concentration and applied weekly via root-zone irrigation. The volume per application was standardized to ensure equal watering across treatments. This design allowed for comparative analysis of FAA dosage effects on lettuce growth within a controlled VF setting.

2.5 Data Collection

Growth data were collected weekly for a total duration of five weeks. Two primary parameters were measured: plant height (in centimeters) and number of leaves. Plant height was measured from the base of the stem to the apex of the tallest leaf using a standard ruler. Leaf number was recorded by manually counting all fully emerged leaves per plant. Observations were recorded for each plant in all treatment groups.

2.6 Statistical Analysis

Data were compiled and analyzed using Microsoft Excel 365. Means and standard deviations were calculated for each treatment group. Growth trends over time were visualized using line graphs for both height and leaf number. Comparative analysis was conducted to determine the most effective FAA concentration for enhancing lettuce growth under the vertical farming system.

3. Results

3.1 Plant Height

The application of Fish Amino Acid (FAA) fertilizer had a notable influence on the plant height of lettuce (*Lactuca sativa*) grown under the vertical farming system. Over a five-week observation period, lettuce treated with FAA showed a consistent and progressive increase in height compared to the control group. The highest average height was observed in plants treated with 35.5 mL FAA (10.95 cm), followed closely by the 30.5 mL treatment group (10.22 cm). The 25.5 mL treatment resulted in slightly lower average plant height (10.91 cm), while the control group, which received no FAA, exhibited the least growth, with a final average height of 6.32 cm.

Although the 35.5 mL FAA treatment produced the tallest plants by week five, the 30.5 mL treatment group displayed a more uniform growth pattern across all weeks and maintained stable development. This suggests that 30.5 mL may represent an optimal balance between nutrient availability and plant uptake efficiency, minimizing any potential nutrient stress or excess. The consistent enhancement of plant height in FAA-treated groups highlights the fertilizer's ability to improve nutrient uptake and stimulate vegetative growth.

The line graph illustrating weekly plant height (Figure 1) clearly depicts the growth trend across all treatment levels. The control line (0 mL FAA) remained the lowest throughout the study. In contrast, the 25.5 mL and 30.5 mL lines showed a steady incline with a slight tapering toward week five, whereas the 35.5 mL line peaked sharply in the final two weeks. These patterns support the conclusion that FAA, particularly at 30.5–35.5 mL concentrations, positively influences height development in lettuce plants grown vertically.

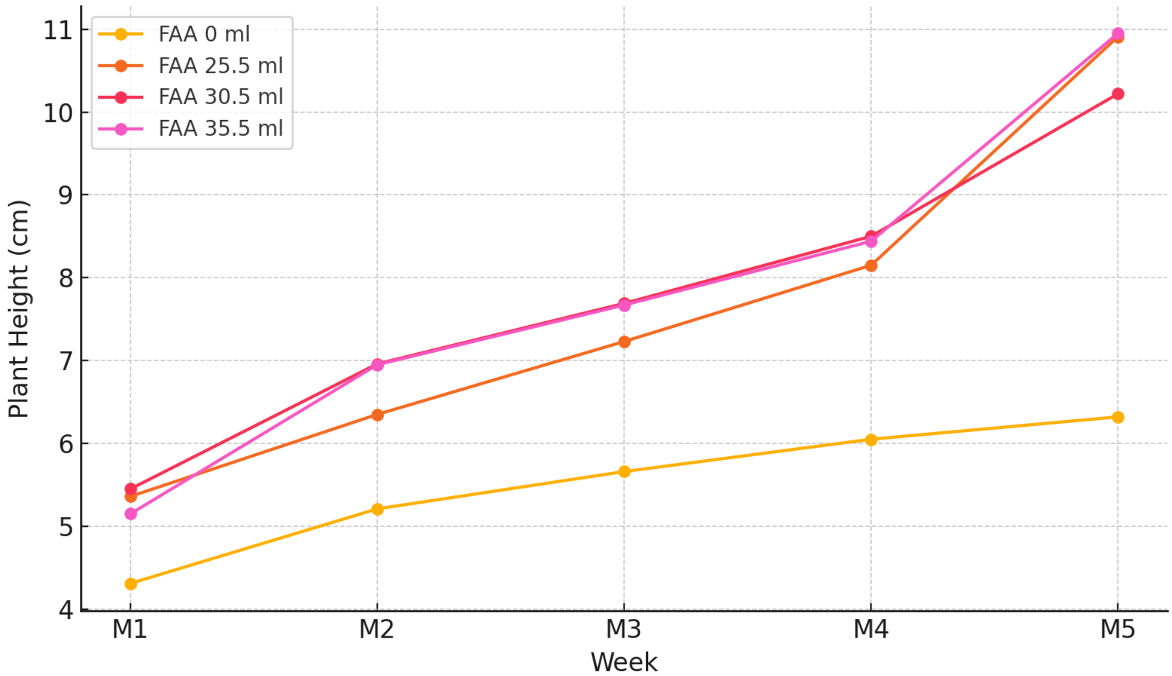

Fig. 1: Weekly average plant height (cm) of lettuce treated with varying concentrations of FAA fertilizer over five weeks.

3.2 Leaf Count

Leaf production was also positively affected by FAA application. At the end of the fifth week, plants treated with 30.5 mL FAA produced the highest average number of leaves (8 leaves), followed by both the 25.5 mL and 35.5 mL treatments, which yielded similar results (8 leaves each). The control group produced the lowest leaf count, averaging only 5 leaves by week five.

Interestingly, while the 35.5 mL group produced slightly more height, it did not significantly exceed the 30.5 mL group in leaf number. This may indicate that although higher FAA concentrations continue to promote vertical growth, they do not proportionally enhance leaf proliferation and may result in diminishing returns. The 30.5 mL treatment showed both high leaf count and uniform growth, suggesting it provides sufficient amino acids and nutrients without inducing potential stress or imbalance.

The leaf count graph (Figure 2) supports this observation, with the 30.5 mL treatment line maintaining the steepest and most stable upward trajectory across the five-week period. The control group's line remains mostly flat, indicating limited leaf development. The 25.5 mL and 35.5 mL treatments show similar growth curves but with minor fluctuations, suggesting variable leaf production responses to slightly suboptimal or excessive FAA dosages.

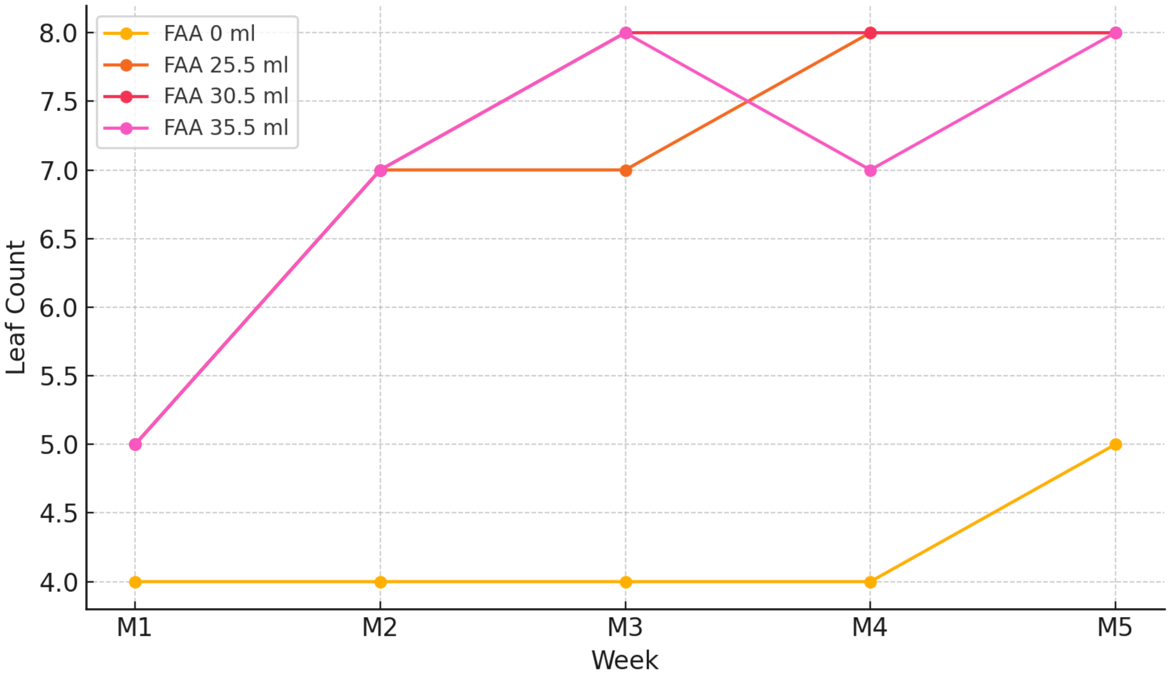

Fig. 2: Weekly average number of leaves per lettuce plant treated with varying concentrations of FAA fertilizer over five weeks.

4. Discussion

The application of Fish Amino Acid (FAA) fertilizer significantly enhanced the growth performance of *Lactuca sativa* (lettuce) cultivated under a vertical farming system. Among the tested concentrations, the 30.5 mL FAA treatment yielded the most consistent and robust outcomes, as evidenced by improvements in both plant height and leaf number. This finding is consistent with previous studies indicating that FAA rich in amino acids, peptides, vitamins, and micronutrients can enhance plant physiological functions by stimulating nitrogen metabolism, chlorophyll biosynthesis, and photosynthetic efficiency (Siddique et al., 2023; Kim et al., 2014). Siddique et al. (2023) further noted that FAA application promoted phototropic responses and nutrient uptake efficiency, leading to more vigorous vegetative development in a variety of crops.

Although the 35.5 mL FAA treatment resulted in the tallest plants, it did not lead to a proportional increase in leaf number, suggesting the existence of an optimal application threshold beyond which additional FAA provides diminishing or non-significant benefits. Similar outcomes were reported by Priyanka et al. (2019), who observed that elevated FAA concentrations failed to further improve vegetative parameters and, in some instances, were associated with reduced chlorophyll content and compromised leaf development. These findings underscore the importance of dose optimization in organic fertilization practices, where excessive nutrient loading may result in osmotic stress or nutrient imbalances, ultimately inhibiting plant performance (Frayco et al., 2023; Nguyen et al., 2019).

The superiority of the 30.5 mL treatment in promoting both vertical growth and foliar expansion highlights the critical role of balanced nutrient delivery. Over-application of organic inputs, though biologically derived, can mirror the adverse effects of chemical overfertilization if not properly managed (Mahmud et al., 2023). The controlled environment provided by the vertical farming system in this study featuring consistent light intensity, temperature, and humidity allowed for the isolation of FAA's specific effects on lettuce growth. Such environmental uniformity is essential for nutrient response assessment, as shown in hydroponic research, where minimizing external variability ensures that growth differences can be attributed to fertilizer treatments (Khan et al., 2025; Resh, 2022).

Beyond its agronomic benefits, FAA also represents a sustainable solution in line with circular economy principles. Its production through the fermentation of fish waste not only mitigates organic waste disposal issues but also enriches the fertilizer with beneficial microbial consortia that improve soil microbial activity, nutrient solubilization, and plant resilience (Siddique et al., 2023; Wahyuni et al., 2021). This dual function as both a growth stimulant and an environmental management tool positions FAA as a compelling alternative to conventional fertilizers in the context of urban and vertical agriculture.

In conclusion, this study demonstrates that a 30.5 mL application of FAA is optimal for promoting *Lactuca sativa* growth in vertical farming conditions, offering a sustainable and efficient nutrient strategy. These results support the broader adoption of FAA in environmentally conscious farming systems and highlight the need for future research exploring its long-term effects, cross-species efficacy, and performance under variable environmental regimes.

5. Conclusion

The findings validate FAA as a promising organic fertilizer that supports sustainable and resource-efficient urban agriculture practices. Its application in vertical farming not only optimizes plant development in space-limited environments but also contributes to environmental conservation by recycling organic waste. This aligns well with global efforts to adopt eco-friendly and circular agricultural systems. Incorporating FAA into nutrient management strategies for leafy vegetables offers an effective alternative to synthetic fertilizers, reducing chemical dependency while maintaining high-quality produce. The vertical farming setup further enhances the applicability of this approach in urban settings, where land scarcity is a major constraint. Future research is recommended to evaluate the long-term effects of FAA on crop yield, nutrient uptake efficiency, and resistance to environmental stress. Additionally, comparative studies involving other organic fertilizers and crop species could broaden the understanding of FAA's potential across different agricultural systems.

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Conflict of Interest

The authors declare no conflicts of interest.

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