

Response of Lettuce (*Lactuca sativa* L.) to Vermicast and Organic Concoction as Solution in Kratky Method in Pet Bottles

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ABSTRACT

Lettuce (*Lactuca sativa* L.) is a high-value leafy vegetable commonly produced in hydroponic systems, yet most nutrient solutions rely on synthetic fertilizers. This study evaluated the growth, yield, and economic viability of lettuce grown using vermicast and organic concoctions as nutrient sources in a Kratky hydroponic system with recycled polyethylene terephthalate (PET) bottles. The experiment was conducted in Lamba, Banga, South Cotabato using a completely randomized design with nine treatments replicated three times. Treatments included a commercial hydroponic solution, diluted vermicast, fermented plant juice (FPJ), fermented fruit juice (FFJ), indigenous microorganisms (IMO), and their combinations with

vermicast. Growth and yield data were analyzed using analysis of variance and Tukey's HSD test at the 5% level of significance through the Statistical Tool for Agricultural Research. Results revealed highly significant treatment effects across growth and yield parameters. The commercial solution produced the highest overall growth and yield, with a mean plant height of 16.67 cm and yield of 261.97 g. However, diluted vermicast produced statistically comparable leaf width, leaf length, and marketable yield, indicating its viability as an organic nutrient source. Standalone FPJ, FFJ, and IMO treatments produced no marketable yield, while combined treatments with vermicast remained inferior to diluted vermicast alone. Economic analysis showed that diluted vermicast achieved the highest return on investment at 387.25%, compared with 124.57% for the commercial control. The findings indicate that diluted vermicast can serve as a sustainable and cost-effective alternative nutrient solution for small-scale hydroponic lettuce production using recycled PET bottles.

Keywords: *Lactuca sativa*, hydroponics, vermicast, organic concoctions, Kratky method, PET bottles, economic analysis

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is a nutritionally important leafy vegetable valued for its vitamins, dietary fiber, phenolic compounds, and antioxidants that contribute to digestive, cardiovascular, anti-inflammatory, and other health benefits (Cervantes et al., 2017; Mulabagal et al., 2010). In the Philippines, lettuce production is commonly concentrated in highland areas such as Benguet, Bukidnon, and Cavite, yet production remains constrained by tropical conditions, soil degradation, water limitations, pest pressure, and the high input requirements of conventional farming (Gonzaga et al., 2017; Singh et al., 2015). These

constraints have encouraged interest in soilless and controlled production methods that can increase crop productivity while reducing land and water demands.

Hydroponics offers a practical response to these production challenges because it enables controlled nutrient delivery without soil. Among available hydroponic systems, the Kratky method is particularly suitable for resource-limited and small-scale producers because it is passive, non-circulating, and does not require electricity, pumps, or aerators (Gumisiriza et al., 2022). The use of recycled PET bottles as plant containers further reduces production cost and supports environmental sustainability by reusing plastic waste (Adriano, 2021; Rohmah et al., 2024).

Despite the advantages of hydroponics, many systems depend on synthetic nutrient solutions. Growing consumer interest in organic and sustainable food production has led to investigations into organic nutrient sources such as vermicast, fermented plant juice, fermented fruit juice, and indigenous microorganisms. Vermicast contains plant-available nutrients, beneficial microorganisms, humic substances, and plant growth regulators that support root development, nutrient uptake, and plant vigor (Arancon et al., 2018; Fortus, 2024; Haghghi et al., 2016). Meanwhile, FPJ, FFJ, and IMO are used in organic and natural farming as plant growth stimulants and microbial inputs, although their performance as primary nutrient sources in hydroponics remains less established (Frayco et al., 2022; Tangpos, 2022).

This study addressed this gap by evaluating the response of lettuce to vermicast and organic concoctions as nutrient solutions under the Kratky method using recycled PET bottles. Specifically, it assessed plant height, leaf length, leaf width, number of leaves, yield, marketable yield, and return on investment. The study also identified which nutrient solution or combination is best suited for PET-bottle-based Kratky lettuce production.

Literature Review

Lettuce Production and Hydroponic Systems

Lettuce is widely cultivated in hydroponic systems because it has a short growth cycle, high market value, and suitability for controlled environments. Soilless systems can improve lettuce productivity and quality compared with open-field systems, particularly where soil conditions or climate limit production (Qadeer et al., 2020; Solis & Jac, 2022). However, the heavy reliance of hydroponics on formulated inorganic nutrient solutions raises concerns about cost, sustainability, and accessibility among small-scale farmers.

The Kratky method is a simplified passive hydroponic system that suspends plant roots above a nutrient solution. As plants consume water and nutrients, an air space develops, allowing roots to access oxygen without mechanical aeration (Kratky, 2000; Gumisiriza et al., 2022). Its simplicity and low operating cost make it especially relevant for urban agriculture, school-based farming, and household vegetable production.

Vermicast and Organic Concoctions as Nutrient Sources

Vermicast and vermicompost are nutrient-rich organic fertilizers produced through earthworm-mediated decomposition. They contain nitrate, phosphorus, potassium, calcium, magnesium, beneficial microorganisms, humic substances, and plant growth hormones that can stimulate root elongation, chlorophyll synthesis, and biomass accumulation (Arancon et al., 2018; Haghghi et al., 2016; Manchal et al., 2023). Fortus (2024) reported that vermicast improved lettuce leaf number, diameter, and biomass, confirming its potential as a growth-promoting organic input.

Fermented Plant Juice, Fermented Fruit Juice, and Indigenous Microorganisms are common bio-organic inputs in natural farming. FPJ is produced through fermentation of fast-growing plant materials and contains nutrients, enzymes, amino acids, organic acids, and growth-promoting substances. FFJ, often prepared from fruits such as banana and papaya, may supply potassium and other growth-promoting

compounds. IMO contributes beneficial microbial populations that support nutrient cycling and plant health in soil-based systems (Frayco et al., 2022; Tangpos, 2022). However, their effectiveness in passive hydroponic systems may be limited because nutrients in organic inputs often require microbial mineralization before they become available to plants (Ahmed et al., 2021; Park & Williams, 2024).

Recycled PET Bottles and Sustainable Urban Agriculture

The use of PET bottles in hydroponic production provides a low-cost and environmentally responsive approach to urban agriculture. PET bottles are accessible, durable, and easy to modify as plant containers and reservoirs. Their reuse reduces plastic waste and makes hydroponic production more affordable for households, schools, and community gardens (Adriano, 2021; Rohmah et al., 2024). When combined with low-cost organic nutrient sources, PET-bottle Kratky systems may offer a practical pathway for sustainable and small-scale vegetable production.

METHODS

Research Design, Locale, and Duration

The study used a single-factor experiment laid out in a completely randomized design with nine nutrient treatments replicated three times. The experiment was conducted from December 2, 2025 to February 16, 2026 at Alamada Compound, Purok Alonto, Lamba, Banga, South Cotabato. The 12-week period covered nutrient preparation, seed germination, transplanting, crop monitoring, harvesting, and data analysis.

Experimental Treatments

The treatments were: T1, commercial hydroponic solution (control); T2, diluted vermicast at 1 kg per 10 L of water; T3, FPJ at 20 ml/L of water; T4, FFJ at 20 ml/L of water; T5, IMO at 20 ml/L of water; T6, vermicast + FPJ; T7, vermicast + FFJ; T8, vermicast + IMO; and T9, vermicast + IMO + FPJ. Each PET bottle received 0.7 L of the assigned nutrient solution.

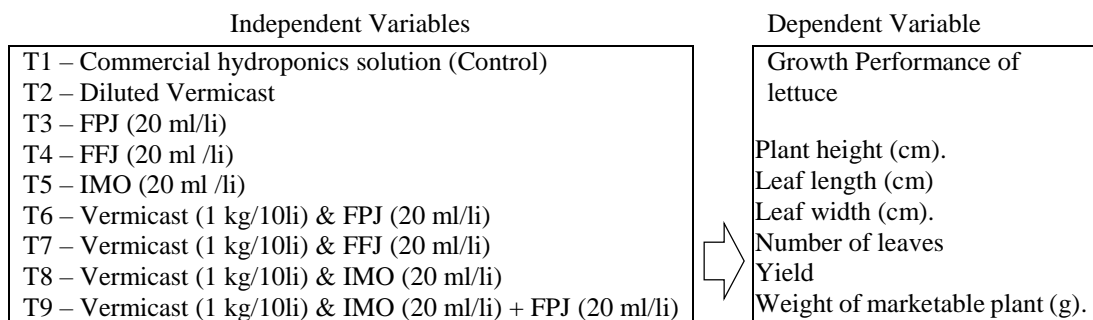


Figure 1. *The Conceptual Framework of the Study*



Figure 2. Representative PET-bottle Kratky setup used in the experiment.

Materials and Crop Establishment

The study used Lollo Bionda lettuce seeds, recycled 1.5-L PET bottles, coco peat, vermicast, Organikian hydroponic concentrated solution, pH-adjusting solution, seedling trays, measuring tools, and materials for the preparation of FPJ, FFJ, and IMO. Lettuce seeds were pre-germinated using the tissue-paper method and sown in seedling trays containing a 1:1 mixture of coco peat and vermicast. After 15 days, healthy seedlings were transplanted into prepared PET bottles containing coco peat and the assigned nutrient solution.



Figure 3. Actual greenhouse setup used to protect the lettuce plants.



Figure 4. *Lettuce seedlings prior to transplanting.*

Preparation and Application of Nutrient Solutions

FPJ was prepared by fermenting chopped kangkong, camote tops, and kakawate leaves with molasses for seven days. FFJ was prepared by fermenting chopped papaya and banana with molasses for seven days. IMO was prepared by culturing microorganisms on cooked rice, mixing the colonized rice with molasses, and fermenting the mixture before extraction. Diluted vermicast was prepared by mixing vermicast with water at a 1:10 ratio. Commercial hydroponic solution was prepared according to the manufacturer's recommendation.



Figure 5. *Preparation of combined organic nutrient solution*



Figure 6. Application of commercial hydroponic solution to PET bottles

Data Collection and Statistical Analysis

Plant height, leaf length, leaf width, and number of leaves were measured at scheduled intervals after transplanting. Yield and marketable yield were measured at harvest by weighing the fresh produce per replication. Economic analysis was conducted using total yield, gross return, treatment cost, net return, and return on investment. Data were analyzed using ANOVA and Tukey's HSD test at the 5% level of significance using the Statistical Tool for Agricultural Research.

RESULTS AND DISCUSSION

Plant Height

The nutrient treatments significantly influenced lettuce plant height. The commercial hydroponic solution produced the tallest plants (16.67 cm), followed by diluted vermicast (13.40 cm). FPJ, FFJ, IMO, and their combinations with vermicast produced shorter plants ranging from 4.17 to 6.43 cm. The superior performance of T1 can be attributed to its balanced and readily soluble macro- and micronutrients, while the favorable performance of T2 reflects the nutrient and growth-promoting properties of vermicast (Arancon et al., 2018; Haghghi et al., 2016). The low growth in FPJ, FFJ, and IMO treatments suggests that these inputs may not provide immediately available nutrients in a passive hydroponic environment where microbial mineralization is limited (Ahmed et al., 2021; Park & Williams, 2024).

Table 1. Average plant height (cm) of lettuce under different nutrient treatments

Treatment	Mean (cm)
T1 - Commercial hydroponic solution	16.67a
T2 - Diluted vermicast	13.40b
T3 - FPJ	4.70c
T4 - FFJ	4.63c
T5 - IMO	4.17c
T6 - Vermicast + FPJ	5.97c
T7 - Vermicast + FFJ	6.03c
T8 - Vermicast + IMO	6.37c
T9 - Vermicast + IMO + FPJ	6.43c
Overall mean	7.60; CV = 14.96%

Note. Means with the same letter are comparable based on Tukey's HSD at the 5% level of significance.



Figure 7. Representative lettuce plant growth in PET-bottle Kratky setup.

Leaf Width and Leaf Length

Leaf width and leaf length were also significantly affected by the nutrient treatments. The commercial solution and diluted vermicast were statistically comparable in both leaf width and leaf length, with T1 recording 6.20 cm leaf width and 10.90 cm leaf length and T2 recording 5.97 cm leaf width and 10.67 cm leaf length. These results indicate that diluted vermicast can support leaf expansion at a level comparable to commercial nutrient solution. In contrast, FPJ, FFJ, IMO, and the combination treatments produced significantly smaller leaves. Since leaf expansion depends strongly on the availability of nitrogen, potassium, calcium, and magnesium, the results suggest that fermented concoctions used alone or mixed with vermicast did not supply sufficient soluble nutrients for optimal leaf development.

Table 2. Average leaf width (cm) of lettuce under different nutrient treatments

Treatment	Mean (cm)
T1 - Commercial hydroponic solution	6.20a
T2 - Diluted vermicast	5.97a
T3 - FPJ	3.23b
T4 - FFJ	3.40b
T5 - IMO	3.43b
T6 - Vermicast + FPJ	3.90b
T7 - Vermicast + FFJ	3.77b
T8 - Vermicast + IMO	3.97b

T9 - Vermicast + IMO + FPJ 4.13b
Overall mean 4.22; CV = 9.41%

Note. Means with the same letter are comparable based on Tukey's HSD at the 5% level of significance.

Table 3. Average leaf length (cm) of lettuce under different nutrient treatments

Treatment	Mean (cm)
T1 - Commercial hydroponic solution	10.90a
T2 - Diluted vermicast	10.67a
T3 - FPJ	4.57b
T4 - FFJ	4.60b
T5 - IMO	4.57b
T6 - Vermicast + FPJ	5.40b
T7 - Vermicast + FFJ	4.77b
T8 - Vermicast + IMO	5.90b
T9 - Vermicast + IMO + FPJ	5.83b
Overall mean	6.36; CV = 11.08%

Note. Means with the same letter are comparable based on Tukey's HSD at the 5% level of significance.



Figure 8. Representative leaf development under PET-bottle Kratky culture

Number of Leaves

The number of leaves differed significantly among treatments. T1 produced the highest number of leaves, followed by T2. Treatments containing only FPJ, FFJ, or IMO produced the fewest leaves, while combination treatments produced intermediate but still low values. Leaf count is a direct indicator of vegetative productivity and is influenced by nitrogen, phosphorus, and other nutrients required for cell division and shoot development. The results confirm that nutrient solubility and availability are critical in passive hydroponic systems.

Table 4. *Average number of leaves of lettuce under different nutrient treatments*

Treatment	Mean
T1 - Commercial hydroponic solution	6a
T2 - Diluted vermicast	5b
T3 - FPJ	3c
T4 - FFJ	3c
T5 - IMO	3c
T6 - Vermicast + FPJ	4c
T7 - Vermicast + FFJ	4c
T8 - Vermicast + IMO	4c
T9 - Vermicast + IMO + FPJ	4c
Overall mean	4; CV = 10.86%

Note. Means with the same letter are comparable based on Tukey's HSD at the 5% level of significance

Yield and Marketable Yield

Yield was highly affected by nutrient formulation. The commercial solution produced the highest total yield (261.97 g), while diluted vermicast produced the second-highest yield (216.57 g). Standalone FPJ, FFJ, and IMO produced extremely low yields, while combination treatments improved yield slightly but remained significantly inferior to diluted vermicast alone. Marketable yield followed a similar pattern, with T1 and T2 statistically comparable. Notably, FPJ, FFJ, and IMO alone produced no marketable yield, indicating that these inputs were inadequate as sole nutrient sources in the Kratky system.

Table 5. *Average yield (g) of lettuce under different nutrient treatments*

Treatment	Mean (g)
T1 - Commercial hydroponic solution	261.97a
T2 - Diluted vermicast	216.57b
T3 - FPJ	9.83c
T4 - FFJ	10.10c
T5 - IMO	9.93c
T6 - Vermicast + FPJ	26.67c
T7 - Vermicast + FFJ	40.00c
T8 - Vermicast + IMO	36.90c
T9 - Vermicast + IMO + FPJ	36.70c
Overall mean	3.96; CV = 21.22%

Note. Means with the same letter are comparable based on Tukey's HSD at the 5% level of significance

Table 6. *Average marketable yield (g) of lettuce under different nutrient treatments*

Treatment	Mean (g)
T1 - Commercial hydroponic solution	261.97a
T2 - Diluted vermicast	203.33a
T3 - FPJ	0b
T4 - FFJ	0b
T5 - IMO	0b
T6 - Vermicast + FPJ	13.23b
T7 - Vermicast + FFJ	20.00b
T8 - Vermicast + IMO	26.90b
T9 - Vermicast + IMO + FPJ	16.77b
Overall mean	60.24; CV = 37.27%

Note. Means with the same letter are comparable based on Tukey's HSD at the 5% level of significance

The comparable marketable yield between T1 and T2 is important because it indicates that diluted vermicast can sustain lettuce growth and produce saleable biomass even without synthetic nutrient solution. However, the reduced productivity of combination treatments suggests possible nutrient antagonism, microbial immobilization, or chemical instability when fermented concoctions were mixed with vermicast. Such instability may affect pH, electrical conductivity, nutrient release, and root uptake in non-circulating systems (Solis & Jac, 2022; Park & Williams, 2024).



Figure 9. Fresh lettuce yield during harvest under commercial hydroponic treatment



Figure 10. Representative harvested marketable lettuce samples.

Cost and Return Analysis

Economic analysis showed that diluted vermicast was the most efficient treatment, achieving the highest ROI of 387.25%. Although the commercial solution produced the highest total yield, its higher input cost reduced its ROI to 124.57%. The standalone fermented concoctions and combination treatments resulted in negative returns because their yields were too low relative to their preparation costs. These results establish diluted vermicast as the most economically feasible nutrient source among the tested treatments for small-scale PET-bottle Kratky lettuce production.

Table 7. *Cost and return analysis per nutrient treatment*

Treatment	Yield (g)	Yield (kg)	Gross Return (P)	Cost (P)	Net Return (P)	ROI (%)
T1 - Commercial solution	262	0.262	47.16	21	26.16	124.57
T2 - Diluted vermicast	216.6	0.217	38.98	8	30.98	387.25
T3 - FPJ	9.83	0.010	1.77	53	-51.23	-96.66
T4 - FFJ	10.10	0.010	1.82	68	-66.18	-97.32
T5 - IMO	9.93	0.010	1.79	50	-48.21	-96.42
T6 - Vermicast + FPJ	26.67	0.027	4.80	61	-56.20	-92.13
T7 - Vermicast + FFJ	40.00	0.040	7.20	76	-68.80	-90.53
T8 - Vermicast + IMO	36.90	0.037	6.64	58	-51.36	-88.55
T9 - Vermicast + IMO + FPJ	36.70	0.037	6.61	127	-120.40	-94.79

Note. Gross return was based on yield multiplied by local market price; ROI = (net return/treatment cost) x 100.

CONCLUSION

The study concludes that nutrient formulation significantly affects the growth, yield, marketable yield, and economic viability of lettuce produced through a PET-bottle Kratky hydroponic system. The commercial hydroponic solution produced the highest overall growth and total yield due to its balanced and readily available nutrients. However, diluted vermicast produced statistically comparable leaf dimensions and marketable yield and generated the highest return on investment, making it the most cost-effective treatment in the study.

Diluted vermicast can therefore serve as a sustainable organic alternative nutrient source for hydroponic lettuce production, especially for small-scale, school-based, urban, and resource-limited farming contexts. Conversely, FPJ, FFJ, and IMO were not effective as standalone nutrient solutions and did not produce marketable yield. Their combinations with vermicast also reduced productivity and profitability compared with diluted vermicast alone, suggesting possible nutrient imbalance or instability in the passive hydroponic system.

Recommendation

Commercial hydroponic solution may be used when the priority is maximizing lettuce growth and yield, especially in larger-scale production systems where input cost can be recovered through volume and market access.

Diluted vermicast is strongly recommended for small-scale hydroponic lettuce growers using the Kratky method in recycled PET bottles because it produced favorable growth, comparable marketable yield, and the highest ROI among the tested treatments.

FPJ, FFJ, and IMO should not be used as sole nutrient sources for lettuce in passive hydroponics unless their nutrient composition, pH, electrical conductivity, and microbial behavior are optimized and validated.

Future studies should test different concentrations, fermentation periods, blending ratios, pH/EC adjustments, and longer cropping cycles to improve the reliability of organic nutrient solutions in hydroponic systems.

Schools and community-based agriculture programs may adopt PET-bottle Kratky systems using diluted vermicast as a low-cost teaching and production model that promotes food security, recycling, and sustainable urban agriculture.

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