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# Utilization of varying levels of fermented kakawate leaf extract as nutrient supplement in hydroponic lettuce production

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## Abstract

This study investigated the effects of fermented kakawate (*Gliricidia sepium*) plant juice (FPJ) as a supplemental nutrient solution in hydroponic lettuce (*Lactuca sativa*) production. The primary objective was to determine the growth response, yield performance, and economic viability of lettuce grown with varying rates of kakawate FPJ combined with reduced concentrations of commercial SNAP nutrient solution. The experiment was laid out in a Completely Randomized Design (CRD) with four treatments replicated four times: 100% SNAP solution (control), and 90% SNAP solution supplemented with 25 ml, 50 ml, and 75 ml of fermented kakawate extract. Results showed that the application of 50 ml FPJ with 90% SNAP solution significantly improved plant height (16.64 cm), root length (16.33 cm), number of leaves (35), and fresh weight (69.25 g) compared to the control. This treatment also yielded the highest net income (₱1,618) and return on investment (206.91%). The study concluded that 50 ml of fermented kakawate extract is the optimal dosage for enhancing lettuce growth and economic return in a hydroponic system. The findings support the use of locally available, low-cost organic inputs like kakawate FPJ as sustainable alternatives to synthetic nutrient solutions, particularly for small-scale and resource-limited farmers.

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## Introduction

Agricultural sustainability and food security have become central concerns globally as the population grows and arable land becomes increasingly limited. Innovations in cultivation practices, such as hydroponics, have emerged as viable solutions to increase food production without further straining land resources. Hydroponics, a method of growing plants in a nutrient-rich water solution without soil, offers benefits like higher yields, faster growth, and reduced pest incidence. However, its reliance on synthetic nutrient solutions raises environmental and economic concerns, particularly for small-scale or organic growers due to the high price of the nutrient solution and the safety of the material for human consumption.

In response to these challenges, researchers and practitioners have begun exploring organic alternatives to synthetic nutrients in hydroponic systems. One such alternative is the use of fermented plant juice (FPJ), a liquid fertilizer derived from plant materials through a natural fermentation process. FPJs are known for their affordability, ease of production, and contribution to sustainable agriculture. Among the various plant sources, kakawate (*Gliricidia sepium*), a nitrogen-rich leguminous tree, has shown potential as an effective organic fertilizer due to its high nutrient content and wide availability in tropical regions.

Kakawate leaves contain essential macro- and micronutrients that can support plant growth, particularly nitrogen, phosphorus, and potassium, which are critical for leafy vegetable development. Through fermentation, these nutrients become more bioavailable, creating a nutrient-dense solution that can be easily absorbed by plants. Moreover, the fermentation process enhances microbial activity, which may contribute to plant health and ecosystem improvement, even in soilless systems like hydroponics.

Lettuce (*Lactuca sativa*), a popular leafy vegetable in hydroponic farming, is highly sensitive to nutrient availability and balance. The crop requires a consistent and adequate nutrient supply to achieve optimal growth, yield, and quality. This sensitivity makes lettuce an ideal test crop for assessing the efficacy of alternative nutrient sources such as kakawate leaf FPJ. Ensuring the correct dosage is applied is equally crucial, as over- or under-application of nutrients can adversely affect plant development.

In recent years, fermented plant juices have gained attention in natural farming practices, particularly in regions promoting sustainable and low-cost agricultural methods. Despite their increasing popularity, limited empirical research exists on the application of FPJs in hydroponic systems, where nutrient delivery mechanisms differ significantly from those in soil-based cultivation. As such, this study fills an important gap by scientifically evaluating the performance of kakawate leaf FPJ in a controlled hydroponic setup.

The ecological benefits of using kakawate as a fertilizer source also merit attention. Kakawate is a fast-growing, nitrogen-fixing tree that contributes to soil fertility and erosion control when grown in agroforestry systems. Utilizing its leaves in FPJ production creates an avenue in the field of hydroponic production as an eco-friendly input which aligns with the broader goals of sustainable agriculture.

Furthermore, this study supports the development of localized nutrient solutions, which main objective is to reduce dependency on imported or commercially produced hydroponic solution. For farmers in rural or low-resource settings, FPJ from kakawate leaves may represent a practical, scalable, and environmentally sound nutrient option. Understanding the appropriate application rate is essential to maximize its benefits without compromising the plant performance. This study aimed to determine the effect of applying kakawate fermented plant juice as nutrient supplement in hydroponic lettuce at varying rates. Specifically, to determine the growth, yield and economics of lettuce as affected by the increasing rates of fermented kakawate juice combined with commercial hydroponic solution.

## Materials and methods

The following materials were used in the study: lettuce seeds, seedling tray, Styrofoam fruit crates, plastic cup, snap solution, kakawater leaves, pail, molasses, scotch tape, strainer, plastic bottles, measuring cups, tape measure, sensitive weighing balance, record notes, and pen.

*Preparation and fermentation of kakawate extract*

Kakawate leaves were collected within the premise of Cagayan State University early in the morning. The leaves were sliced using sharp knives to hasten the fermentation process. Equal amount of molasses was mixed with kakawate leaves and was placed in a clean container. The mixture was stirred thoroughly and covered with clean paper, secured tightly using rubber bands or packaging tape. The fermentation process was allowed to proceed for seven days. After fermentation, the juice was extracted using clean cheesecloth and stored in sterilized plastic bottles in a cool, dry place until application.

*Lettuce seedling production*

Lettuce seeds are first sown in seedling trays or plug trays filled with a sterile, well-draining medium such as cocopeat or peat moss. The trays are maintained under greenhouse with adequate humidity and light to ensure uniform germination. Seedlings are grown until they develop 2 to 3 true leaves or within two weeks. During this period seedlings are ready for transplanting.

*Mixing of growing media*

The growing medium used for transplanting is prepared by mixing inert substrates such as partially decomposed cocopeat and carbonized rice hull in equal proportions. The mixture is designed to offer good aeration and water retention without causing waterlogging, creating an ideal environment for root growth. Thorough mixing ensures uniformity of the growing medium's physical properties.

*Experimental design and treatment*

The Completely Randomized Design (CRD) was used in the experiment to test the following treatments which was replicated four (4) times. The following treatments were:

Treatment 1- Control (25 ml SNAP solution)
Treatment 2- 90% SNAP solution + 25 ml Fermented Kakawate Extract
Treatment 3- 90% SNAP solution + 50 ml Fermented Kakawate Extract
Treatment 4- 90% SNAP solution + 75 ml Fermented Kakawate Extract

*Transplanting in a cup*

Seedlings are then transplanted from the plugs into cups to suit with the hydroponic system being used, such as a floating raft system. Care is taken to gently spread out the roots and plant the seedlings at an appropriate depth to prevent damage and support healthy development.

*Application of nutrient solution*

The nutrient solution is prepared by blending varying concentrations of Kakawate Leaf Fermented Plant Juice (FPJ) with the standard hydroponic nutrient solution, according to the experimental design (e.g., 0%, 5%, 10%, and 15% FPJ). This solution is consistently applied to ensure adequate nutrient availability. Parameters such as pH (maintained between 5.5 and 6.5) are regularly monitored to optimize nutrient uptake. The nutrient solution is refreshed or replaced periodically, typically on a weekly basis, to maintain its quality and effectiveness.

*Pest control*

To protect the lettuce plants from pest, regular monitoring is conducted for common pests such as aphids and whiteflies. Biological or organic control measures are preferred to prevent contamination of the FPJ and nutrient solution. Additionally, cleanliness and proper ventilation are maintained to reduce the risk of pest infestations and diseases.

*Harvesting*

Harvesting is carried out when the lettuce reaches marketable size or optimal maturity, which generally occurs 30 to 45 days after transplanting depending on the variety and growing conditions. Careful harvesting techniques are used to avoid damaging the plants and roots.

*Data gathered*

Eight (8) sample plants were randomly selected from each treatment group for data collection. These selected plants were marked with tape for easy identification. The following parameters were measured during the study:

*Average height per plant (cm)*

Plant height was measured in centimeters from the base to the tip of the longest leaf. Measurements were taken at harvest. The average height was calculated based on the data collected from the sample plants.

*Average number of leaves per plant*

The number of leaves was counted every seven days. Only fully emerged leaves on each sample plant were included in the count, and the average was calculated per treatment group.

*Average length of roots per plant (cm)*

Root length was measured in centimeters after harvesting. The measurement was taken from the base of the stem to the tip of the longest root for each sample plant.

*Average fresh weight of leaves per sample (g)*

The fresh weight of leaves was determined by weighing all harvested leaves from the sample plants within each treatment. The total weight was then divided by the number of sample plants to obtain the average fresh weight per plant.

*Return on investment analysis*

The cost of materials and labor from planting to harvesting was recorded. ROI was calculated using the formula, net income is equal to gross income minus the total cost of production.

**Results and discussion**

*Plant height (cm)*

Fig. 1 shows the average plant height of lettuce as affected by the application of varying levels of fermented kakawate juice. Among the treatments, Treatment 3 (90% SNAP solution + 50 ml fermented kakawate extract) recorded the tallest plant with a mean of16.64 cm. The ranking was followed by plants in Treatment 4 (90% SNAP + 75 ml FKWE) and Treatment 2 (90% SNAP + 25 ml FKWE) with mean heights of 14.69 cm and 13.55 cm, respectively. The control plants (Treatment 1: 25 ml SNAP solution only) recorded the shortest plant height of 12.38 cm.

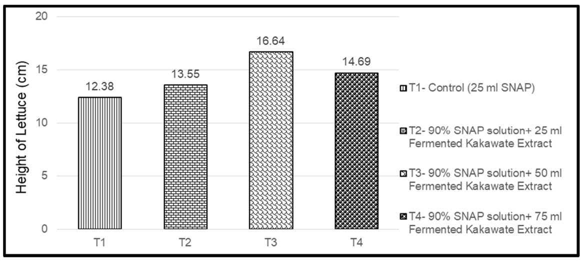


**Fig. 1.** Average height of lettuce as affected by the application of fermented kakawate extract in combination with SNAP nutrient solution

Analysis of variance indicated that the differences among treatments were highly significant at the 1% level, demonstrating that the inclusion of fermented kakawate extract had a marked effect on lettuce plant height. Further comparison using the least significant difference test showed that Treatment 3 significantly outperformed all other treatments. Treatment 4 also resulted in significantly greater plant height than Treatments 2 and 1. Similarly, Treatment 2 was statistically superior to the control (Treatment 1).

These results suggest that supplementing SNAP nutrient solution with fermented kakawate extract significantly enhances plant growth, with the 50 ml rate (Treatment 3) emerging as the most effective dosage. This supports the potential of fermented plant-based bio-stimulants in improving the vegetative performance of lettuce under controlled conditions. The enhanced plant height observed in treatments supplemented with fermented kakawate extract may be attributed to its rich content of nitrogen, phosphorus, and potassium that are known to stimulate plant growth (Mbah *et al.*, 2010; Osondu and Anyanwu, 2018). *Gliricidia sepium* has been widely documented as an effective green manure and organic input, improving soil fertility and plant vigor through nutrient cycling and microbial activity enhancement (Aroeira *et al.*, 2015).

*Root length*

Fig. 2 shows the average root length of lettuce as affected by the application of fermented kakawate (*Gliricidia sepium*) extract in combination with SNAP nutrient solution. Treatment 3 (90% SNAP + 50 ml fermented kakawate extract) yielded the longest roots, with a mean length of 16.33 cm. This was followed by Treatment 4 (90% SNAP + 75 ml FKWE) with 14.69 cm, Treatment 2 (90% SNAP + 25 ml FKWE) with 13.13 cm, and the control (Treatment 1: 25 ml SNAP only) with the shortest roots at 12.45 cm.

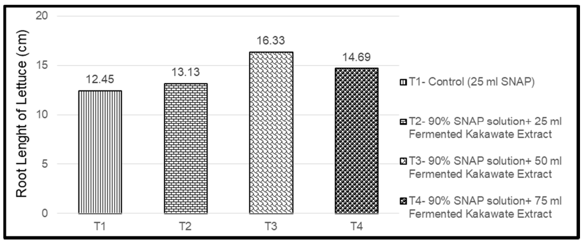


**Fig. 2.** Average root length of lettuce as affected by the application of fermented kakawate extract in combination with SNAP nutrient solution

Analysis of variance revealed that the treatment effects on root length was highly significant. Treatment 3 was significantly superior to all other treatments. Treatment 4 also resulted in significantly longer roots than Treatments 2 and 1. However, Treatment 2 is not statistically different when compared control plants. The marked increase in root length with fermented kakawate extract suggests an improvement in root development, likely due to the nutrient-rich profile and growth-promoting properties of the extract.

These findings could be explained that *Gliricidia sepium* is known to enhance root system development through its high nitrogen content and allelopathic compounds such as flavonoids, which influence root elongation and lateral root formation (Ghosh *et al.*, 2004; Miah *et al.*, 2020). Furthermore, fermented plant extracts contribute beneficial microbial populations and organic acids that enhance root architecture by improving nutrient uptake and soil microecology (Gutiérrez-Miceli *et al.*, 2008; Olivares *et al.*, 2015).

*Number of leaves per plant*

The number of leaves of lettuce per hill as affected by the application of fermented kakawate extract in combination with SNAP nutrient solution is shown in Fig. 3. Treatment 3 (90% SNAP solution + 50 ml fermented kakawate extract) produced the highest leaf count, with a mean of 35 leaves per plant. This was followed by Treatment 4 (90% SNAP + 75 ml FKWE) with 31 leaves, and Treatment 2 (90% SNAP + 25 ml FKWE) with 25 leaves. The Treatment 1, receiving only 25 ml SNAP solution recorded the lowest number of leaves at 15.

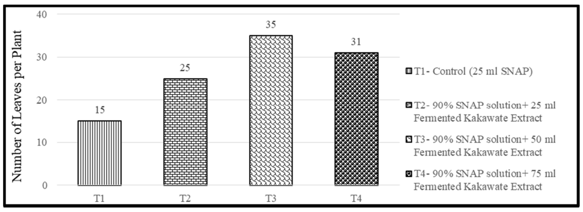


**Fig. 3.** Average number of leaves of lettuce per plant as affected by the application of fermented kakawate extract in combination with SNAP nutrient solution

The analysis of variance indicated significant effect at the 1% level. The least significant difference confirmed that each treatment mean was significantly different from the others, with Treatment 3 resulting in a significantly higher number of leaves than all other treatments. Treatment 4 also outperformed Treatments 2 and 1, while Treatment 2 significantly exceeded the control.

These results confirm that incorporating fermented kakawate extract can enhance foliage development in lettuce, a critical factor for yield in leafy vegetable production. These results are corroborated by existing studies which reported that *Gliricidia sepium*, when used as green manure or fermented extract, enhances vegetative growth by supplying readily available nitrogen and growth-regulating compounds such as saponins and phenolics (Osondu and Anyanwu, 2018; Gutiérrez-Miceli *et al.*, 2008). Moreover, fermented plant extracts are known to stimulate photosynthetic efficiency and leaf expansion due to their influence on hormone-like activity and microbial population enhancement (Olivares *et al.*, 2015; Rady *et al.*, 2020).

*Weight of lettuce per hill*

Fig. 4 shows the average weight of lettuce per hill affected by the application of varying levels of fermented kakawate in combination with SNAP nutrient solution. Treatment 3 (90% SNAP solution + 50 ml fermented kakawate extract) yielded the highest fresh weight averaging 69.25 grams per hill. This was followed by Treatment 4 (90% SNAP + 75 ml FKWE) with 65.75 g, Treatment 2 (90% SNAP + 25 ml FKWE) with 55.45 g, and the control (Treatment 1, SNAP solution only) with the lowest mean of 46.60 g.

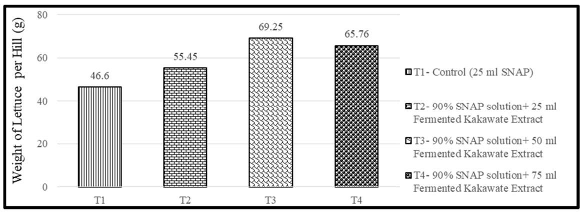


**Fig. 4.** Average weight of lettuce per hill as affected by the application of fermented kakawate extract in combination with SNAP nutrient solution

Analysis of variance revealed significant difference among the different treatments tested at 1% level degree of significance. The least significant difference confirmed that Treatment 3 recorded the heaviest weight of lettuce per hill but not statistically different when compared to plants in Treatment 4. Significant difference was observed when Treatment 3 and Treatment 2 is being compared to Treatments 2 and 1. Likewise, Treatment 2 is significantly greater than the control plants (Treatment 1). The results of the study explained that fermented kakawate extracts enhance plant biomass of weight by increasing nutrient uptake efficiency, improving chlorophyll synthesis, and stimulating photosynthetic activity (Olivares *et al.*, 2015; Rady *et al.*, 2020).

*Economic analysis*

The economic performance of the four treatments is summarized in Table 1. Among all treatments, Treatment 3 (90% SNAP solution + 50 ml fermented kakawate extract) generated the highest gross sales at ₱2,400, followed by Treatment 4 (₱2,160), Treatment 2 (₱1,920), and Treatment 1 (₱1,680). Correspondingly, net income was also highest in Treatment 3, amounting to ₱1,618.00 significantly surpassing that of the other treatments.

**Table 1.** Cost and return analysis of lettuce as affected by the application of fermented kakawate extract in combination with SNAP nutrient solution

| Treatment | Gross sales | Total production cost | Net income | ROI% |
|---|---|---|---|---|
| T1- 25 ml SNAP solution | 1680 | 702 | 978 | 139.32 |
| T2- 90% SNAP + 25 ml FKWE | 1920 | 732 | 1188 | 162.30 |
| T3- 90% SNAP + 50 ml FKWE | 2400 | 782 | 1618 | 206.91 |
| T4- 90% SNAP + 75 ml FKWE | 2160 | 832 | 1328 | 159.62 |

In terms of return on investment, Treatment 3 again outperformed all others, with an ROI of 206.91%, indicating that every peso invested returned more than double in profit. Treatment 2 and Treatment 4 also yielded favorable ROI values of 162.30% and 159.62%, respectively, while the control (Treatment 1) had the lowest ROI at 139.32%.

These findings demonstrate that integrating 50 ml of fermented kakawate extract into the nutrient management regimen not only enhances plant growth and yield but also maximizes economic returns. Although Treatment 4 involved higher input costs due to the increased volume of fermented extract, it did not proportionally increase income, resulting in a lower ROI compared to Treatment 3. This suggests that Treatment 3 strikes an optimal balance between input cost and productivity.

## Conclusion

Based on result, it can be concluded that the incorporation of fermented kakawate plant juice as a nutrient supplement in hydroponic lettuce production positively affects growth and yield. Specifically, the use of 50 ml of fermented kakawate juice combined with 90% of the standard commercial nutrient solution resulted in the most favorable outcomes in terms of plant height, root development, leaf production, and weight of plant per hill. Over-application beyond this optimal dosage did not significantly improve results, indicating that there is a threshold to the beneficial effects of the fermented extract. It is also recommended that hydroponic lettuce growers incorporate 50 ml of fermented kakawate juice plus 90% of commercial nutrient solution to optimize plant growth and maximize economic returns.

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