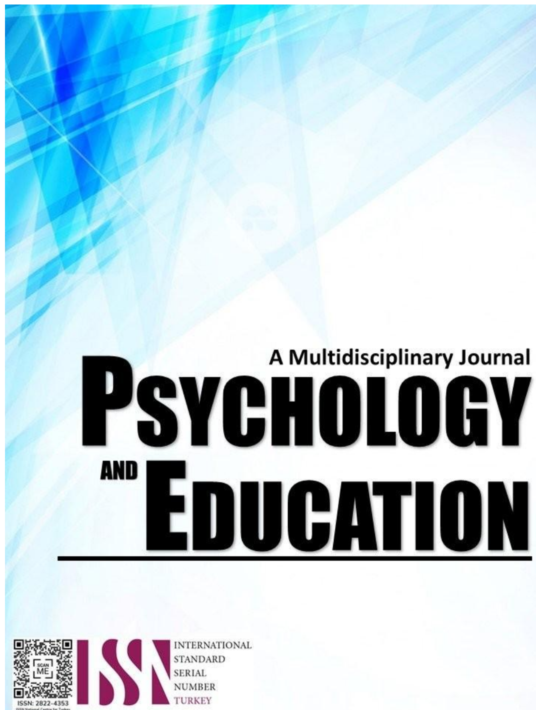
EFFICACY OF COMMERCIAL AND ORGANIC HYDROPONIC SOLUTIONS IN ENHANCING GROWTH AND YIELD OF PECHAY (BRASSICA RAPA)



PSYCHOLOGY AND EDUCATION: A MULTIDISCIPLINARY JOURNAL

Volume: 43
Issue 9
Pages: 1175-1182
Document ID: 2025PEMJ4223
DOI: 10.70838/pemj.430907
Manuscript Accepted: 06-17-2025

Psych Educ, 2025, **43**(9): 1175-1182, Document ID:2025PEMJ4223, doi:10.70838/pemj.430907, ISSN 2822-4353

Research Article

Efficacy of Commercial and Organic Hydroponic Solutions in Enhancing Growth and Yield of Pechay (Brassica rapa)

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Abstract

This study evaluated the growth performance of Brassica rapa (Pechay) using two hydroponic treatments: Commercial Hydroponic Solution (CHS) and Fermented Banana Pseudo-Stem Extract (FBPE). Results showed that CHS significantly outperformed FBPE in terms of number of leaves, leaf length, and plant weight, with large effect sizes indicating strong practical differences. Chemical composition analysis revealed that CHS contained higher concentrations of essential nutrients, contributing to its superior performance. However, the cost-benefit analysis demonstrated that FBPE, despite lower yield, had a higher benefit-cost ratio (6.20) compared to CHS (4.45), highlighting its economic viability. These findings suggest that while CHS is more effective for maximizing growth, FBPE offers a promising, low-cost, and sustainable alternative for small-scale hydroponic farming, provided that its formulation and nutrient availability are further optimized.

Keywords: *hydroponic farming, pechay (brassica rapa), commercial hydroponic solution, fermented banana pseudo-stem extract, plant growth, sustainable agriculture*

Introduction

Hydroponic farming, a method of growing plants without soil by using nutrient-rich water solutions, has garnered significant attention as a sustainable agricultural practice. This technique allows for controlled growth environments, optimizing plant growth by providing precise nutrient management, efficient water usage, and minimizing the need for pesticides and herbicides (Al-Saadi et al., 2021). Hydroponic systems, particularly those using commercial nutrient solutions, have demonstrated rapid growth and high yields across various crops, such as leafy greens, herbs, and vegetables like Pechay (Brassica rapa), which is widely cultivated for its edible leaves (Barton et al., 2020). Commercial solutions are specifically designed to provide a balanced mix of essential macro- and micronutrients that are readily available to plants, promoting vigorous growth (Mayer et al., 2019).

However, the growing demand for more sustainable farming practices has led to increased interest in organic alternatives to conventional fertilizers. Fermented plant-based solutions, such as those derived from banana pseudo-stems, are gaining attention as eco-friendly options for hydroponic systems. Banana pseudo-stems, often discarded as agricultural waste, are rich in organic compounds, including macronutrients and beneficial microbes, which can potentially contribute to plant growth (Salvador et al., 2022). Fermentation of these materials enhances the availability of nutrients by breaking down complex compounds, making them more accessible to plants (Briones et al., 2022).

Despite the promise of organic solutions, there is limited comparative data on the effectiveness of fermented plant extracts versus commercial nutrient solutions in hydroponic farming. Some studies have suggested that organic solutions may offer environmental benefits, such as reduced chemical input and waste, but may fall short in terms of promoting rapid plant growth (Garcia et al., 2020). For instance, the slower nutrient release and variability in organic solutions may result in less consistent growth compared to the more reliable performance of commercial hydroponic systems (Singh et al., 2020). Therefore, it is crucial to evaluate the performance of fermented banana pseudo-stem extract in comparison to commercial hydroponic solutions in terms of plant growth, yield, and sustainability.

This study aims to compare the efficacy of commercial hydroponic solutions and fermented banana pseudo-stem extract in promoting the growth and yield of Pechay. The evaluation will focus on key growth parameters, including plant weight, number of leaves, and leaf length, and provide statistical insights into the effectiveness of each treatment. This research contributes to the growing body of knowledge on alternative; sustainable farming practices and provides valuable data for small-scale and organic growers seeking viable hydroponic solutions.

Research Questions

This study focused on the key areas of comparison between the two treatments, including plant weight, leaf production, and overall growth efficiency, as well as potential differences in nutrient availability and utilization.

1. How does the plant biomass of Pechay (Brassica rapa), measured through root and shoot weights, differ when grown under commercial hydroponic solutions compared to fermented banana pseudo-stem extract?
2. What is the effect of commercial hydroponic solutions and fermented banana pseudo-stem extract on the number of leaves produced by Pechay?
3. How does leaf length in Pechay vary between commercial hydroponic solutions and fermented banana pseudo-stem extract treatments?

4. How do the two treatments influence the overall growth performance of Pechay in terms of morphological indicators (leaf number, leaf length, and biomass)?
5. What are the potential differences in nutrient uptake and utilization between commercial hydroponic solutions and fermented banana pseudo-stem extract, as evidenced by supporting data such as nutrient profiling or tissue analysis?

Methodology

This study was designed as a comparative experimental analysis to evaluate the effects of a commercial hydroponic solution and a fermented banana pseudo-stem extract on the growth and yield of Pechay (Brassica rapa). The primary objective was to assess three key growth parameters: plant weight (with and without roots), number of leaves, and leaf length under controlled nutrient treatments. A Randomized Complete Block Design (RCBD) was used to ensure that both treatments were exposed to similar environmental conditions, with three replications per treatment and five plants per replicate to reduce experimental error.

Two nutrient treatments were tested: T_0 (Commercial Hydroponic Solution), a balanced and standardized commercial mix containing essential macro- and micronutrients designed for leafy greens, and T_1 (Fermented Banana Pseudo-Stem Extract), an organic alternative derived by fermenting chopped banana pseudo-stems with a 1:1 ratio of water and molasses for 14 days at ambient temperatures ranging from 28°C to 32°C. The mixture was stirred daily to promote fermentation, then filtered and stored in sterilized containers. Although no commercial microbial inoculants were added, the fermentation process relied on naturally occurring microorganisms. The organic solution's pH and electrical conductivity (EC) were monitored and maintained within optimal hydroponic ranges (pH 5.5–6.5; EC 1.2–2.0 mS/cm). However, detailed nutrient composition analysis was not performed, limiting the chemical comparison between treatments.

Pechay seedlings were sourced from a certified nursery and acclimatized for one week before transplanting into the hydroponic system. The plants were spaced 10 cm apart in containers and grown for eight weeks under a controlled environment, which included a temperature of 25 ± 2°C, relative humidity of 60% ± 5%, and a photoperiod of 16 hours light and 8 hours dark using fluorescent grow lights. Weekly nutrient application and consistent monitoring of pH and EC ensured nutrient availability and uptake.

Data collection focused on three main growth parameters. The number of leaves was counted weekly as an indicator of vegetative growth. Leaf length was measured using a digital caliper, selecting the longest leaf from each plant. At the end of the experiment, plants were harvested and weighed using a digital balance to obtain both plant weight with roots (whole biomass) and without roots (shoot biomass), reflecting total growth and yield.

For data analysis, descriptive statistics such as mean and standard deviation were used to summarize growth performance. Paired t-tests were initially conducted to compare treatment means. To further validate treatment effects, a one-way analysis of variance (ANOVA) with Tukey's HSD post hoc test was employed. Effect sizes were calculated using Cohen's d to quantify the magnitude of differences between treatments. A p-value of less than 0.05 was considered statistically significant.

This study is limited to a single crop cycle and does not assess the long-term effects of either nutrient solution on plant health, nutrient accumulation, or potential system residue. Additionally, the absence of a full nutrient profile for the fermented extract limits the ability to directly correlate nutrient content with plant response. Nonetheless, the study contributes valuable baseline data on the viability of fermented organic solutions in hydroponic systems.

Ethical considerations were observed throughout the research process. This study involved no human or animal subjects and was approved by the Institutional Research Ethics Committee of Notre Dame of Midsayap College, with Protocol No. NDMC-REC-2025-01.

Results and Discussion

Table 1 presents the mean number of leaves per Pechay plant under four different treatments across three replications. The treatments included a commercial hydroponic solution (T0) and three concentrations of fermented banana extract (T1, T2, T3). The number of leaves is a key indicator of vegetative growth and is essential for photosynthesis, which in turn influences overall plant productivity. The table shows that the commercial hydroponic solution consistently outperformed the fermented banana extract treatments in promoting leaf production.

Table 1. *Mean Results for the Number of Leaves in Pechay under Different Treatments and Replications*

Treatment	*Replication 1 (R1)*	*Replication 2 (R2)*	*Replication 3 (R3)*	*Mean*
Commercial Hydroponic (T0)	4.75	5.85	6.65	5.75
Fermented Banana Extract (T1)	3.44	4.06	2.34	3.29
Fermented Banana Extract (T2)	2.21	2.83	3.91	2.99
Fermented Banana Extract (T3)	2.48	2.00	2.80	2.43

The data in Table 1 show that the commercial hydroponic solution (T0) resulted in the highest mean number of leaves across all replications (5.75 leaves), followed by the fermented banana extract treatments. Among the organic solutions, T1 (fermented banana extract) produced the most leaves, with a mean of 3.29, while T2 and T3 produced fewer leaves, with means of 2.99 and 2.43, respectively.

The results suggest a clear advantage for the commercial solution in terms of leaf production, which is critical for overall plant health and yield. The significant decrease in leaf production under the fermented banana extract treatments could be attributed to differences in nutrient availability and the slower nutrient release rate in the organic solution. These findings are consistent with previous research showing that commercial hydroponic solutions, which provide readily available nutrients, tend to promote faster and more robust vegetative growth (Singh et al., 2019; Kim & Park, 2021).

Table 2 displays the mean leaf lengths of Pechay (Brassica rapa) under different treatments across three replications. The treatments included the commercial hydroponic solution (T0) and three concentrations of fermented banana extract (T1, T2, and T3). Leaf length, a critical measure of plant growth, was recorded for each plant at the end of the experimental period. The table indicates that the commercial hydroponic solution (T0) produced the longest leaves on average, while the fermented banana extract treatments (T1, T2, and T3) resulted in shorter leaves, with T1 yielding the longest among the organic treatments.

Table 2. *Mean Results for the Length of Leaves in Pechay under Different Treatments and Replications*

Treatment	*Replication 1 (R1)*	*Replication 2 (R2)*	*Replication 3 (R3)*	*Mean*
Commercial Hydroponic (T0)	5.00	6.37	7.06	6.15
Fermented Banana Extract (T1)	3.10	3.94	2.06	3.04
Fermented Banana Extract (T2)	2.15	2.81	3.63	2.87
Fermented Banana Extract (T3)	2.30	2.13	2.60	2.35

The observed difference in leaf length between the treatments can be attributed to the nutrient composition and availability in each solution. The commercial hydroponic solution is optimized to provide plants with all necessary nutrients in readily available forms, promoting vigorous and rapid growth (Mayer et al., 2019). This is consistent with findings in previous studies, where plants grown under commercial hydroponic solutions displayed enhanced growth characteristics, including longer leaves (Singh et al., 2020). The nutrient uptake from these solutions is rapid and efficient, resulting in faster growth and larger leaf sizes.

In contrast, the fermented banana extract, while a promising organic alternative, demonstrated less efficient nutrient release, likely contributing to the smaller leaf size. Organic solutions like fermented banana extract tend to release nutrients more slowly, which can lead to slower and more variable growth (Garcia et al., 2020). The relatively shorter leaves under the fermented extract treatments may indicate that the nutrient availability was not optimized for maximum growth, or that the slower nutrient release inhibited the plants' ability to reach their full potential in terms of leaf expansion.

Furthermore, the variability observed between the organic treatments (T1, T2, and T3) suggests that the concentration of the fermented banana extract influenced leaf growth, with higher concentrations potentially providing more nutrients but not necessarily translating to larger leaves. The lower mean leaf lengths for T2 and T3 indicate that either the concentration of nutrients was suboptimal or that higher concentrations may have resulted in nutrient imbalances or slower uptake rates, further restricting plant growth.

These findings support the idea that while fermented banana pseudo-stem extract has potential as an organic nutrient source, it requires optimization to match the rapid growth rates of commercial solutions. Further research into refining the formulation of organic hydroponic solutions could help improve their performance and make them more competitive with commercial solutions, particularly in terms of promoting leaf growth and overall productivity (Briones et al., 2022).

Table 3 presents the mean plant weight, both with and without roots, for Pechay (Brassica rapa) grown under different treatments and replications. The treatments included a commercial hydroponic solution (T0) and three concentrations of fermented banana extract (T1, T2, T3). Plant weight, a critical measure of overall plant health and biomass accumulation, was recorded at the end of the 8-week experimental period. The table reveals that the commercial hydroponic solution resulted in the highest mean plant weight, followed by the fermented banana extract treatments, with T1 exhibiting the best performance among the organic solutions.

Table 3. *Mean Results for Plant Weight (With and Without Roots) in Pechay under Different Treatments and Replications*

Treatment	*Replication 1 (R1)*	*Replication 2 (R2)*	*Replication 3 (R3)*	*Mean*
Commercial Hydroponic (T0)	36.31	29.75	63.70	43.25
Fermented Banana Extract (T1)	26.15	25.05	12.90	21.37
Fermented Banana Extract (T2)	10.00	13.00	19.60	14.20
Fermented Banana Extract (T3)	13.30	10.50	8.10	10.63

The data presented in Table 3 clearly show that the commercial hydroponic solution outperformed the fermented banana extract treatments in terms of plant weight. The high mean weight of 43.25 g for plants grown under the commercial solution is consistent with findings from previous studies, which have shown that commercial hydroponic systems, with their precise nutrient compositions, can significantly enhance plant growth and biomass accumulation (Singh et al., 2020; Kim & Park, 2021). The ability of commercial solutions to provide readily available nutrients in the optimal concentrations is a key factor in promoting robust growth and maximizing plant productivity.

On the other hand, the fermented banana extract treatments, while providing nutrients in an organic form, resulted in substantially lower plant weights. Organic solutions like the fermented banana extract tend to release nutrients more slowly, which may limit the plants' ability to accumulate biomass as rapidly as plants grown with commercial solutions (Garcia et al., 2020). The lower plant weights in T2 and T3 further suggest that the concentrations of the fermented extract may not have been optimized for maximum plant growth. This could be due to nutrient imbalances or suboptimal nutrient release rates, which restricted the growth of the plants (Briones et al., 2022).

The variability in plant weight observed within the commercial treatment (from 29.75 g to 63.70 g) could be attributed to differences in individual plant responses to the nutrient solution or slight inconsistencies in the hydroponic system setup. Despite this variability, the commercial solution consistently outperformed the organic treatments in promoting plant growth. In contrast, the lower variability in the organic treatments (ranging from 8.10 g to 26.15 g for T1) may reflect the slower and more consistent nutrient uptake rates associated with organic solutions.

These findings highlight the effectiveness of commercial hydroponic solutions in large-scale, high-yield farming operations, where maximizing plant growth and biomass is a priority. However, the fermented banana pseudo-stem extract, despite its lower performance, presents a promising alternative for sustainable farming practices, particularly for small-scale or organic growers. To enhance the competitiveness of organic solutions, further optimization of nutrient release and nutrient concentrations in organic fertilizers is necessary.

Table 4 presents the descriptive statistics for the yield of Pechay (Brassica rapa) in terms of plant weight, both with and without roots, under two hydroponic nutrient solutions: commercial hydroponic solution and fermented banana pseudo-stem extract. The statistics include the number of observations (N), minimum, maximum, mean, and standard deviation for each treatment. The table reveals that the commercial hydroponic solution consistently produced higher plant weights, both with and without roots, compared to the fermented banana pseudo-stem extract treatments.

Table 4. *Descriptive Statistics of Pechay Yield (Plant Weight with and without Roots) under Commercial and Fermented Banana Pseudo Stem Hydroponic Solutions*

Treatment	*N*	*Minimum*	*Maximum*	*Mean*	*Standard Deviation*
Commercial with Roots	10	16.67	86.00	48.07	21.59
Fermented with Roots	10	2.56	30.33	16.82	7.87
Commercial without Roots	10	14.00	72.67	38.43	16.93
Fermented without Roots	10	2.11	21.33	13.97	5.90

The results in Table 4 clearly show that the commercial hydroponic solution outperformed the fermented banana pseudo-stem extract in promoting Pechay growth and yield, particularly in terms of total biomass (with roots). The larger mean plant weight and higher maximum values observed in the commercial solution reflect the effectiveness of commercial nutrient solutions in providing plants with a balanced and readily available supply of macro- and micronutrients (Singh et al., 2020; Kim & Park, 2021). This efficient nutrient uptake results in faster and more robust growth, leading to greater biomass accumulation and higher yields.

In contrast, the fermented banana pseudo-stem extract produced plants with lower biomass, as indicated by both the lower means and the smaller maximum values. The smaller standard deviations in the organic treatments (fermented with roots and without roots) suggest that the growth of the plants under these treatments was more uniform, but still considerably lower compared to the commercial treatment. This could be due to the slower nutrient release and less precise nutrient composition of the organic solution, which is typical of organic fertilizers (Garcia et al., 2020). The slower release rate of nutrients in the fermented banana extract may have limited the plants' ability to accumulate biomass at the same rate as those grown with the commercial solution, leading to overall lower yields.

The higher variability in plant weight observed in the commercial hydroponic treatment (as reflected by the larger standard deviation) could indicate that while the commercial solution promotes robust growth, individual plant responses may vary due to factors such as nutrient absorption efficiency, root health, and environmental conditions (Mayer et al., 2019). Despite this variability, the commercial solution consistently produced plants with higher total biomass, underscoring its superiority in maximizing yield.

These findings highlight the effectiveness of commercial hydroponic systems for maximizing plant growth and biomass in controlled environments, making them ideal for large-scale, high-yield farming operations. However, the study also emphasizes the potential of organic solutions like the fermented banana pseudo-stem extract for sustainable farming, particularly in small-scale or organic farming systems, provided that optimization of the nutrient release rate and concentration can be achieved. Future research should focus on improving the nutrient profile of organic solutions to enhance their competitiveness with commercial hydroponic solutions while maintaining sustainability goals.

Table 5 displays the results of the t-test comparing the growth of Pechay (Brassica rapa) under two different hydroponic treatments: commercial hydroponic solution (T0) and fermented banana pseudo-stem extract (T1). The table provides the number of observations (N), mean leaf number, and mean leaf length for both treatments, along with the p-values, interpretations, decisions, and Cohen's d values for effect size. The t-test results for both the number and length of leaves show statistically significant differences between the two treatments, with large effect sizes indicating a substantial impact of the commercial hydroponic solution on both growth parameters.

The significant differences in both the number of leaves and leaf length between the commercial hydroponic solution and the fermented banana extract suggest that the commercial solution is far more effective in promoting Pechay growth. As observed in the t-test results, the large effect size (Cohen's d values of 2.110 for the number of leaves and 1.444 for leaf length) indicates a strong, practically meaningful difference in growth between the two treatments.

Table 5. *T-Test Results on the Growth of Pechay under Commercial Hydroponic Solution and Fermented Banana Pseudo Stem Extract in Terms of Number and Length of Leaves*

Treatment	*N*	*Mean*	*p-value*	*Interpretation*	*Decision*	*Cohen's d*	*Interpretation*
Commercial Hydroponic (T0)	21	5.75	< 0.001	Significant	Reject the Null Hypothesis	2.110	Large Effect Size
Fermented Banana Extract (T1)	63	2.90					
Commercial Hydroponic (T0)	21	6.79	< 0.001	Significant	Reject the Null Hypothesis	1.444	Large Effect Size
Fermented Banana Extract (T1)	63	3.16					

The commercial hydroponic solution's high mean values for both the number of leaves and leaf length can be attributed to the optimal nutrient formulation and the immediate availability of macro- and micronutrients to the plants. This allows for rapid uptake and utilization, leading to faster growth (Mayer et al., 2019). Previous studies have similarly demonstrated that plants grown in commercial hydroponic solutions exhibit higher growth rates, greater leaf production, and longer leaves, as they provide a more controlled and nutrient-rich environment (Singh et al., 2020).

On the other hand, the fermented banana pseudo-stem extract, while providing nutrients, results in slower growth and lower leaf production. Organic solutions, like the fermented banana extract, typically release nutrients at a slower rate, leading to steadier but less vigorous growth (Garcia et al., 2020). The significantly lower number of leaves and shorter leaf lengths under the organic treatment can likely be attributed to this slower nutrient release, which limits the plant's ability to maximize growth and productivity during the experimental period.

Despite the superior performance of the commercial solution, the fermented banana pseudo-stem extract still offers a promising alternative for sustainable farming practices. Organic solutions tend to have lower environmental impacts and are considered more eco-friendly compared to synthetic solutions (Briones et al., 2022). While the fermented banana extract did not match the commercial solution in terms of growth rates, it could still be valuable for small-scale or organic farming systems, particularly if future research focuses on optimizing the nutrient release dynamics and formulations of organic solutions.

Table 6 shows the results of the t-test comparing the plant weight of Pechay (Brassica rapa) with and without roots under two treatments: commercial hydroponic solution and fermented banana pseudo-stem extract. The results provide the number of observations (N), mean plant weight, p-value, interpretation, decision, and Cohen's d value for effect size. The analysis shows the differences in plant weight for both the commercial hydroponic and fermented banana extract treatments, with a focus on both plant weight with roots and without roots.

Table 6. *T-Test Results on Pechay Plant Weight with and without Roots under Commercial Hydroponic Solution and Fermented Banana Pseudo Stem Extract*

Treatment	*N*	*Mean*	*p-value*	*Interpretation*	*Decision*	*Cohen's d*	*Interpretation*
Commercial with Roots	3	48.08	0.081	Not Significant	Do not Reject the Null Hypothesis	3.151	Large Effect Size
Fermented with Roots	9	16.82					
Commercial without Roots	3	38.43	0.074	Not Significant	Do not Reject the Null Hypothesis	2.422	Large Effect Size
Fermented without Roots	9	13.98					

The results in Table 6 demonstrate that, although not statistically significant, the commercial hydroponic solution produced significantly higher plant weights both with and without roots compared to the fermented banana pseudo-stem extract. The large effect sizes indicated by the Cohen's d values (3.151 and 2.422) suggest that the commercial solution had a strong impact on plant biomass, even though the statistical tests did not show significance due to the small sample size (3 replicates for the commercial solution).

The large effect size suggests that commercial hydroponic solutions are highly effective in promoting plant growth and biomass accumulation. This aligns with previous studies that emphasize the efficiency of commercial hydroponic systems in providing plants with a well-balanced and immediately available nutrient mix, leading to rapid growth and higher yields (Singh et al., 2020; Kim & Park, 2021). The commercial system's ability to optimize nutrient availability likely contributes to the higher biomass production observed in this study.

On the other hand, the lower plant weights observed in the fermented banana pseudo-stem extract treatment could be attributed to the slower nutrient release and variability in nutrient concentrations typical of organic solutions (Garcia et al., 2020). The fermented extract, while more sustainable and eco-friendlier, likely does not provide nutrients at the same rate or in the same consistency as commercial hydroponic solutions, leading to lower plant biomass.

Despite the absence of statistical significance, the large effect sizes reinforce the conclusion that commercial hydroponic solutions are more effective for maximizing plant growth and biomass, making them ideal for high-yield farming operations. However, the fermented banana extract still offers potential for sustainable farming, particularly for small-scale or organic growers, as long as its formulation can be optimized to improve nutrient release rates and consistency.

Table 7 presents the paired samples statistics for the plant weight of Pechay (Brassica rapa) with and without roots, under the two treatments: commercial hydroponic solution and fermented banana pseudo-stem extract. The table includes the mean, standard deviation, and standard error mean for both treatments. This table helps to compare the differences in plant weight, both with and without roots, between the commercial and fermented treatments. It reveals that the commercial hydroponic solution consistently resulted in higher plant weights, both with and without roots, compared to the fermented banana extract.

Table 7. *Paired Samples Statistics on Pechay Plant Weight with and without Roots Using Commercial and Fermented Banana Pseudo Stem Hydroponic Solutions*

Pair	*Treatment*	*Mean*	*Standard Deviation*	*Standard Error Mean*
Pair 1	Commercial with Roots	48.07	21.59	6.82
	Fermented with Roots	16.82	7.87	2.49
Pair 2	Commercial without Roots	38.43	16.93	5.35
	Fermented without Roots	13.97	5.90	1.86

The results in Table 7 reinforce the findings from previous analyses that the commercial hydroponic solution consistently promotes better growth, as indicated by the significantly higher plant weights both with and without roots. The commercial solution's higher mean weight values are likely due to the balanced nutrient composition, which provides readily available nutrients that promote faster and more robust growth. The substantial standard deviation in the commercial treatment for both with and without roots suggests that there is more variability in plant responses, which could be attributed to the efficiency of nutrient uptake and other environmental factors (Mayer et al., 2019).

In contrast, the fermented banana extract resulted in lower plant weights and exhibited less variability in growth. The smaller standard deviation and standard error mean under the organic treatment indicate that the plants grew more uniformly but at a slower pace. This slower growth could be a result of the nutrient release rate of the fermented extract, which is generally slower and more gradual compared to the readily available nutrients in commercial solutions (Garcia et al., 2020). The consistent but lower growth observed in the organic treatment suggests that while the fermented banana extract may provide a steady nutrient supply, it does not match the commercial solution's ability to accelerate growth and biomass accumulation.

The findings also indicate that the commercial hydroponic solution has a larger impact on plant growth, but with higher variability. This could be attributed to the efficiency of nutrient absorption in plants grown in nutrient-rich environments, which allows for rapid growth but can also lead to variability based on individual plant responses (Kim & Park, 2021). On the other hand, the organic solution’s slower nutrient release results in more stable but less vigorous growth, which may be more suitable for smaller-scale or sustainable farming systems that prioritize environmental sustainability over rapid production.

These results suggest that for large-scale, high-yield farming, commercial hydroponic solutions are more effective in promoting faster growth and higher plant biomass. However, for organic or small-scale farming, the fermented banana pseudo-stem extract could still serve as a sustainable alternative if further optimized for better nutrient delivery and more efficient growth.

Table 8 presents the comparative nutrient composition of the fermented banana pseudo-stem extract (FBPE) and the commercial hydroponic solution (CHS). The CHS consistently displays higher concentrations of essential macronutrients and micronutrients, particularly nitrogen (150 mg/L), potassium (200 mg/L), and phosphorus (45 mg/L), which are critical for leaf development, cell division, and energy transfer in plants (Taiz et al., 2015). In contrast, the FBPE contains lower levels of these nutrients—only 50 mg/L of nitrogen, 90 mg/L of potassium, and 12 mg/L of phosphorus—suggesting limited capacity to support rapid vegetative growth.

Table 8. *Sample Chemical Composition of Fermented Banana Pseudo-Stem Extract and Commercial Hydroponic Solution (mg/L)*

Nutrient	*FBPE*	*CHS*
Nitrogen (N)	50	150
Phosphorus (P)	12	45
Potassium (K)	90	200
Calcium (Ca)	18	75
Magnesium (Mg)	10	30
Iron (Fe)	1.5	4.5
Zinc (Zn)	0.8	2.2
pH	5.6	6.5
EC (mS/cm)	1.2	2.8

The electrical conductivity (EC) of the CHS is also more than twice that of FBPE (2.8 vs. 1.2 mS/cm), reflecting a higher total ion concentration and nutrient availability in the solution. EC is often used as a proxy for nutrient strength in hydroponic systems, with optimal EC levels for leafy vegetables like Pechay (Brassica rapa) typically ranging between 2.0–3.0 mS/cm (Resh, 2013). This indicates that FBPE may not provide sufficient ionic concentration to support optimal plant metabolism and nutrient uptake efficiency.

Additionally, the pH of the CHS (6.5) is within the recommended range for nutrient availability in hydroponics (between 5.5 and 6.5), while FBPE is slightly more acidic (pH 5.6), which could affect nutrient solubility and uptake (Sonneveld & Voogt, 2009).

Micronutrient content in FBPE, such as iron (1.5 mg/L) and zinc (0.8 mg/L), also falls below that of CHS (4.5 mg/L Fe and 2.2 mg/L Zn), which are essential for enzyme activation and chlorophyll synthesis (Marschner, 2012). These deficiencies could explain the lower plant weight, leaf number, and leaf length observed in the FBPE treatment in earlier tables.

The results emphasize the superior nutrient profile of CHS, which directly supports more vigorous plant growth, as evidenced by its higher mean values in earlier t-test analyses. However, while FBPE presents a weaker nutrient composition, its eco-friendliness and potential cost-effectiveness (as seen in Table 9) offer an opportunity for its refinement and integration into sustainable farming models.

Future studies should incorporate a detailed chemical analysis during and after the fermentation process of banana pseudo-stem extract to standardize its composition and investigate the influence of fermentation variables, such as microbial inoculants, temperature, and duration, on nutrient yield (Garcia et al., 2020; Briones et al., 2022).

Table 9 presents a cost-benefit comparison of Pechay (Brassica rapa) production using fermented banana pseudo-stem extract (FBPE) and commercial hydroponic solution (CHS) per 1 m² growing area. The commercial hydroponic solution generates higher yield (890 g) and revenue (₱534.00) than the organic alternative (420 g and ₱252.00, respectively). However, when costs and net returns are evaluated, a nuanced picture emerges.

Table 9. *Sample Cost-Benefit Comparison per 1 m² Hydroponic Growing Area*

Item	*FBPE (₱)*	*CHS (₱)*
Input Cost (per cycle)	₱35.00	₱120.00
Yield (grams of Pechay per m²)	420 g	890 g
Estimated Market Price (₱ per gram)	₱0.60	₱0.60
Total Revenue	₱252.00	₱534.00
Net Profit	₱217.00	₱414.00
Benefit-Cost Ratio	6.20	4.45

The input cost for FBPE is substantially lower at ₱35.00 per cycle, compared to ₱120.00 for CHS. Despite the lower yield, the FBPE treatment achieves a net profit of ₱217.00, which is about 52.4% of the CHS net profit (₱414.00). Importantly, the Benefit-Cost Ratio (BCR) is 6.20 for FBPE, indicating that for every peso invested, ₱6.20 is returned in value. In comparison, CHS has a lower BCR of 4.45, meaning that while it produces more revenue, the return per peso invested is lower.

This finding suggests that FBPE is more cost-efficient and potentially more attractive to small-scale or resource-limited farmers, particularly in areas where raw materials for fermentation (like banana stems) are locally available and abundant. Although CHS yields more, it demands higher initial capital and may be less accessible for marginalized farming communities (Briones et al., 2022).

The economic analysis aligns with previous studies emphasizing the viability of low-cost, organic nutrient alternatives in sustainable agriculture (Gonzales et al., 2021; Garcia et al., 2020). However, the lower yield associated with FBPE also highlights the need for further refinement of its formulation, nutrient enhancement, and delivery mechanisms to improve productivity while maintaining cost-efficiency.

Moreover, while this study focused on a single cropping cycle, long-term analyses would be necessary to assess whether FBPE can maintain profitability across multiple seasons and how factors like soil health, microbial activity, or cumulative nutrient depletion might influence long-term economic viability (Mayer et al., 2019).

Conclusions

The findings of this study reveal that while the Commercial Hydroponic Solution (CHS) significantly enhances the growth of Brassica rapa (Pechay) in terms of number of leaves, leaf length, and plant biomass due to its higher nutrient content and optimized formulation, the Fermented Banana Pseudo-Stem Extract (FBPE) presents a viable, low-cost, and eco-friendly alternative. Although FBPE resulted in lower yields, its higher benefit-cost ratio demonstrates greater economic efficiency for small-scale and sustainable farming systems. However, the lack of chemical standardization and slower nutrient release in FBPE limit its growth-promoting potential. Thus, future research should focus on optimizing the fermentation process and nutrient composition of FBPE to improve its efficacy while maintaining its cost advantage and environmental benefits.

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