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Comparative Study on the Effects of Food Waste versus Chemical Fertilizer on *Brassica rapa chinensis* (Pak Choy)

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ABSTRACT

This study evaluates the comparative efficacy of food waste versus commercial chemical fertilizer on the agronomic performance of *Brassica rapa chinensis* (Pak Choy). The experiment was conducted within a controlled greenhouse environment at Polytechnic Nilai, Negeri Sembilan, over a 30-day cultivation period. The methodology involved three distinct treatments: food waste, chemical fertilizer (NPK 15:15:15), and a control group receiving no fertilizer amendment. Growth parameters, including plant height, leaf count, and post-harvest fresh weight, were measured to assess yield. The results demonstrate that the food waste compost treatment yielded significantly higher growth metrics compared to both the chemical fertilizer and the control group. Consequently, this study posits that food waste is a viable and effective alternative to synthetic fertilizers, offering a dual solution for reducing chemical dependency in agriculture and optimizing urban food waste management strategies.

1. Introduction

Modern agriculture is currently facing major challenges in increasing crop yields to meet the increasing demand for food as the world's population grows. Most farmers rely on chemical fertilizers to quickly and easily increase crop yields, but excessive use of chemical fertilizers leads to serious negative impacts on the environment. Excessive use of chemical fertilizers causes water pollution through leaching of nutrients into groundwater and river systems, which in turn leads to eutrophication and loss of aquatic biodiversity. In addition, chemical fertilizers also contribute to the deterioration of soil quality by reducing soil organic matter, increasing soil acidity, and reducing soil biological activity that is essential for plant growth.

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At the same time, the issue of food waste management, especially in urban areas, is becoming increasingly critical. The rapid growth of urban populations has led to an increase in the amount of food waste thrown away every day. Food waste that is not properly managed will create various environmental problems such as greenhouse gas emissions, air pollution from open burning, and pressure on limited landfill sites.

Therefore, there is an urgent need to find more sustainable alternatives in agriculture and food waste management. Composting food waste into organic fertilizer is one promising method to address both of these issues simultaneously. Composting food waste is not only able to continuously provide essential nutrients to plants but can also significantly improve soil structure and quality. This study was conducted to scientifically evaluate the effectiveness of food waste compost compared to chemical fertilizers in supporting the growth of *Brassica Rapa Chinensis* 'Pak Choy', thus providing a practical solution to the challenges of sustainable agriculture and urban waste management.

2. Literature Review

According to Ameera [1], food waste compost contains essential nutrients such as nitrogen, phosphorus, potassium, and high organic matter, capable of supporting plant growth by providing nutrients in stages. In addition, food waste compost increases soil water holding capacity, reduces nutrient leaching, and improves overall soil structure.

In addition, Aziz *et al.*, [2] in their study found that Brassica plants given organic fertilizer such as compost showed better growth compared to plants using chemical fertilizer alone. This organic fertilizer increases the activity of soil microorganisms which are important in the process of decomposing organic matter, thus making nutrients more easily absorbed by plant roots.

Furthermore, study by Smith and Doe [3] further strengthens the evidence for the effectiveness of using food waste compost, especially in growing leafy vegetables such as Pak Choy. This compost not only provides nutrients, but also promotes healthy soil microbiota, which is important in supporting more sustainable crop growth.

Apart from increasing crop yields, the use of composting food waste helps in overcoming the growing problem of urban solid waste management Smith and Doe [4]. Reusing food waste through the composting process can reduce greenhouse gas emissions that are usually produced from conventional waste disposal processes such as landfilling.

According to a study by Yu *et al.*, [5], continuous application of food waste compost can increase soil organic carbon content, which in turn improves soil physical properties such as aggregation, aeration, and water holding capacity. This is particularly important in the context of urban agriculture, which often faces the challenges of limited and less fertile soil.

In addition, a study by Zhao *et al.*, [6], also showed that the use of organic fertilizers such as food waste compost can increase plant resistance to plant diseases and environmental stress, compared to plants that only receive chemical fertilizers which can cause nutrient imbalance and soil structure degradation in the long term.

Thus, the integration of food waste composting in agricultural systems not only promotes agricultural productivity but also plays an important role in sustainable waste management strategies and sustainable urban agriculture.

3. Study Methodology

This study was conducted in a controlled greenhouse environment at Politeknik Nilai, Negeri Sembilan, for a duration of 30 days. The 30-day timeframe was chosen to evaluate the initial

vegetative growth phase of the plants. A completely randomized experimental design (CRD) was employed, utilizing 30 healthy and uniform *Brassica rapa chinensis* 'Pak Choy' seedlings. These were divided into three treatment groups, each consisting of three replications with 10 seedlings per replication. The planting media for all treatments used a consistent ratio of 3:2:1 (topsoil, organic matter, and sand). The experimental treatments were defined as follows:

- **Treatment 1:** 100 grams of food waste compost per plant.
- **Treatment 2:** 30 grams of NPK chemical fertilizer (15:15:15) per plant.
- **Treatment 3:** A control group receiving no additional fertilizer amendment.

3.1 Scope and Parameter Measurements

The study focused on agronomic growth performance rather than soil chemical properties or economic analysis. Parameters evaluated weekly throughout the 30-day period included:

- **Plant Height (cm):** Measured from the soil base to the highest point of the plant.
- **Number of Leaves:** Total count of leaflets per plant.
- **Plant Fresh Weight (grams):** Total wet mass recorded immediately after harvest.

While these parameters provide a clear indication of biomass accumulation, this study did not measure soil microbial activity, long-term soil structure changes, or environmental impact assessments, as this activity along with cost-analysis were outside the scope of this initial 30-day study.

3.2 Statistical Analysis

Data were analysed at the end of the experiment using one-way ANOVA to determine significant differences between treatment means. Duncan's post hoc test was applied at a significance level of $p < 0.05$.

Table 1

Comparison of final growth results (summary table)

Treatment	Final Height (cm)	Final Leaf Count	Final Fresh Weight (g)
Food Waste	11.9	10	420
NPK Fertilizer	11.5	8	401
Control Group	10.7	7	298

3. Methodology Study

This study was conducted in the greenhouse of Nilai Polytechnic, Negeri Sembilan for 30 days, using a completely randomized experimental design (CRD). A total of 30 healthy and uniform *Brassica Rapa Chinensis* 'Pak Choy' seedlings were planted and divided into three treatment groups, each consisting of three replications with 10 seedlings per replication. The planting media for all pack Choi vegetable plants used a ratio of 3:2:1, which is 3 parts top soil, 2 parts organic matter and 1 part sand. The experimental treatment as shown in Figure 1 consisted of:

- i. Treatment 1: 100 grams of food waste per plant
- ii. Treatment 2: NPK chemical fertilizer (15:15:15) of 30 grams per plant.
- iii. Treatment 3: Control without any additional fertilizer.



Fig. 1. Transplanting young Brassica Rapa Chinensis 'Pak Choy' in media treatment

Each treatment was given at the beginning of planting and watered consistently using a drip irrigation system to ensure that each plant received the same amount of water. Parameters evaluated throughout the experiment included plant height (cm), number of leaves (leaflets), and plant wet weight after harvest (grams).



(a)



(b)

Fig. 2. Data collection of Brassica Rapa Chinensis 'Pak Choy', (a) plant height & (b) weight plant

Data as shown in Figure 2 were collected weekly and analysed at the end of the experiment using one-way ANOVA statistical analysis to determine significant differences between treatments. Duncan's post hoc test at a significance level of $p < 0.05$.

4. Result and Data Analysis

The results obtained from this study clearly show significant differences in the growth parameters of Brassica Rapa Chinensis 'Pak Choy' based on the type of treatment used. Graphs 1, 2 and 3 show the complete results.

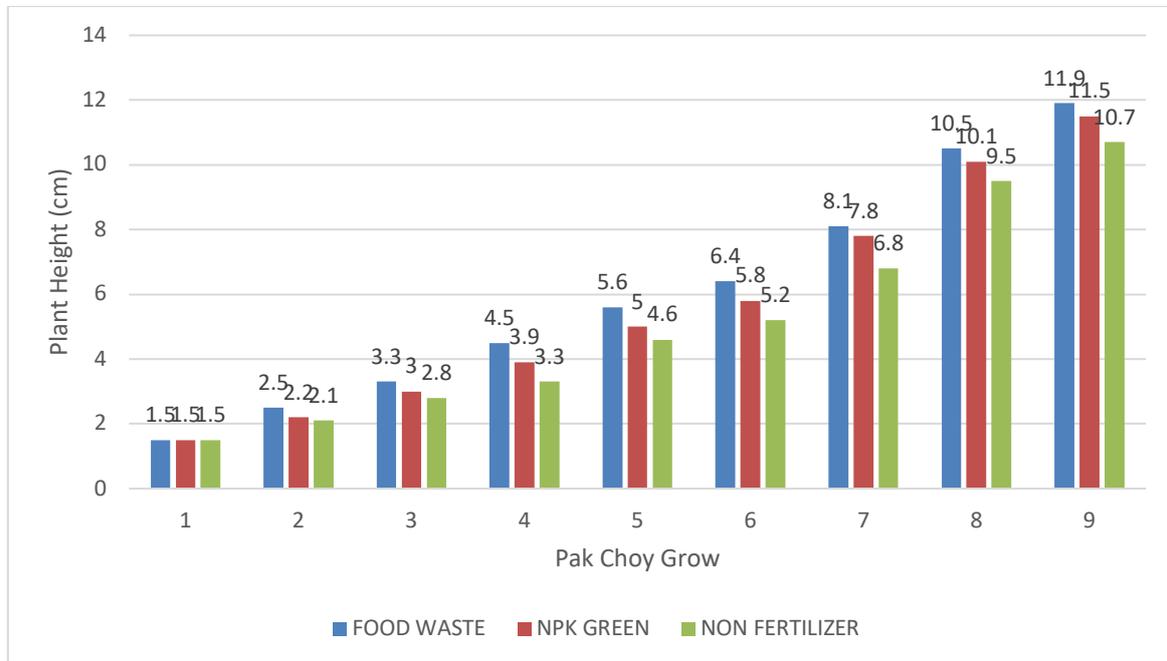


Fig. 3. Comparison of plant height versus type

Fig. 3 illustrates the comparative growth of Pak Choy plants over nine intervals, testing the efficacy of Food Waste and NPK Green fertilizer against a non-fertilized control group. At the initial measurement (interval 1), all plant groups started at a uniform baseline height of 1.5 cm, ensuring a fair comparison. As the growing period progressed, a clear trend emerged showing that both fertilizer treatments promoted greater height than the control group.

The Food Waste treatment consistently yielded the tallest plants at almost every measurement point after the baseline. By the final measurement (interval 9), the plants grown with food waste reached the maximum average height of 11.9 cm. The NPK Green fertilizer also performed well, closely following the food waste group and consistently surpassing the non-fertilized plants. It ended with a final height of 11.5 cm.

The non-fertilizer group showed the slowest growth rate throughout the experiment, resulting in the shortest final average height of 10.7 cm. The data suggests that while both fertilizers improved plant height compared to using nothing, the organic Food Waste was slightly more effective than the chemical NPK Green fertilizer in promoting the vertical growth of Pak Choy in this experiment.

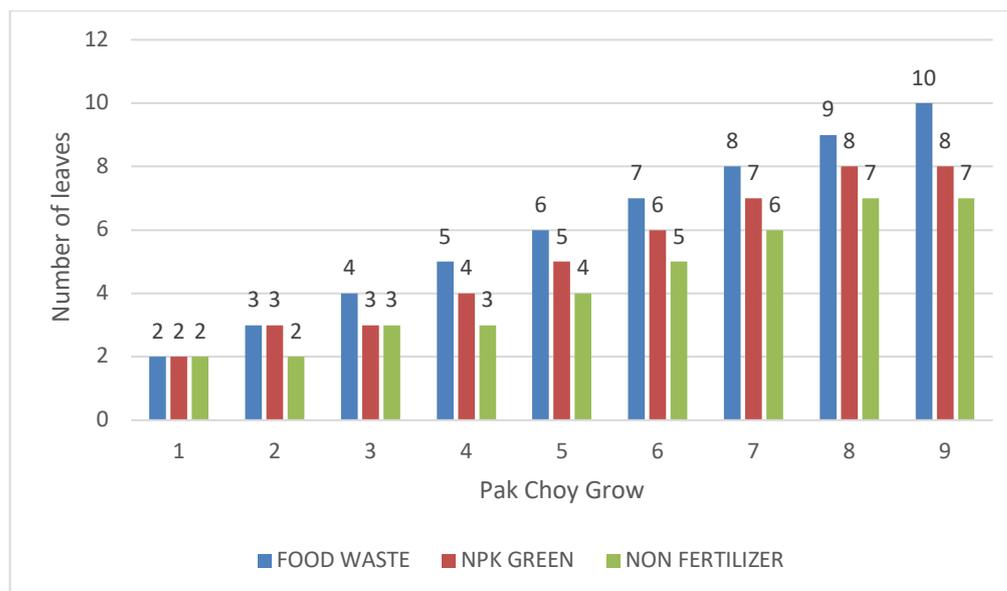


Fig. 4. Comparison of number of tree leaves versus treatment type

Fig. 4 focuses on the number of leaves produced by the Pak Choy plants over nine growth intervals. Similar to the plant height data, this metric is crucial for leafy vegetables like Pak Choy, as leaf count directly correlates to yield:

- i. Initial Uniformity: At the start of the experiment (Interval 1), all three groups (Food Waste, NPK Green, and Non-Fertilizer) began with an identical average of 2 leaves. This confirms that the test subjects started on an equal footing.
- ii. Performance of Food Waste Compost (Blue Bars): The Food Waste treatment demonstrated the most consistent and aggressive growth.
 - a. Steady Increase: It gained roughly one leaf per interval steadily from Interval 3 onwards.
 - b. Highest Yield: It consistently outperformed the other two groups, ending with the highest count of 10 leaves at Interval 9.
 - c. No Plateau: Notably, while the other groups stopped producing new leaves between Interval 8 and 9, the Food Waste group continued to grow (increasing from 9 to 10 leaves), suggesting it was still actively supporting vegetative growth.
- iii. Performance of NPK Green (Orange Bars): The chemical fertilizer showed moderate results.
 - a. It generally produced 1 to 2 fewer leaves than the food waste compost in the later stages.
 - b. Plateau Effect: Between Interval 8 and Interval 9, the leaf count remained stagnant at 8 leaves, indicating that vegetative growth may have slowed down or halted earlier than in the organic compost group.
- iv. Performance of Non-Fertilizer (Green Bars): As expected, the control group showed the least development.
 - a. It consistently lagged the fertilized groups.
 - b. Like the NPK group, it also plateaued at the end, remaining stuck at 7 leaves for the final two intervals.

Fig. 4 reinforces the findings from fig. 1. The Food Waste was not only superior in promoting height but also significantly more effective at generating biomass (leaves). The ability of the Food Waste group to continue producing leaves in the final interval while the NPK and Non-Fertilizer groups stalled suggests that the organic compost may provide a more sustained nutrient release that supports longer-term growth.

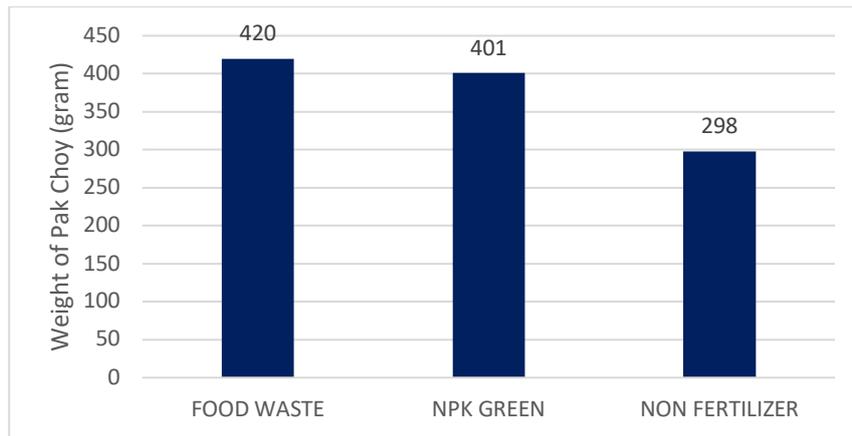


Fig. 5. Comparison of tree weight versus treatment type

Fig. 5 presents the final **weight of the Pak Choy** in grams, which is arguably the most critical metric for farmers as it represents the actual harvestable yield.

- i. Superior Performance of Food Waste Compost: The Food Waste treatment produced the heaviest plants, with an average weight of 420 grams.
 - a. This represents the highest yield among all three groups.
 - b. It suggests that the organic nutrients in the compost were effectively converted into plant mass, likely due to better soil structure or nutrient uptake facilitated by compost.
- ii. Strong Performance of NPK Green: The NPK Green fertilizer followed closely behind, yielding an average weight of 401 grams.
 - a. While effective, it produced approximately 19 grams less per plant compared to the Food Waste group.
 - b. This indicates that while chemical fertilizers are efficient, the organic option performed slightly better in this specific trial.
- iii. Lower Yield in Non-Fertilizer Group: The Non-Fertilizer control group produced significantly lighter plants, weighing only 298 grams.
 - a. There is a massive gap of 122 grams between the Food Waste group and the control group.
 - b. This confirms that without added nutrition, the plants struggle to reach their full potential in terms of mass, even if they manage to grow in height or produce leaves.

This graph provides the most definitive proof of the efficacy of the treatments. While the height and leaf count (from previous graphs) showed gradual differences, the weight metric shows a distinct advantage for the Food Waste. It confirms that using food waste not only creates taller and leafier plants, but significantly heavier and more robust crops compared to using no fertilizer or even standard chemical NPK.

In conclusion fig. 1 shows that the height of the plant was the highest with Food Waste Compost reaching 11.9 cm, Chemical Fertilizer 11.5 cm, Control 10.7 cm. This shows the highest growth consistently in plants treated with food waste. The increase in height supports the highest number of leaves in fig. 2 by Pak Choy plants on Food Waste with 10 leaves compared to 8 for Chemical Fertilizer (NPK Gren 15:15:15) and 7 for the control without fertilizer.

The findings in fig. 3 show that food waste compost can significantly increase the growth rate of Pak Choy with the highest tree weight comparison of 420 g in trees using food waste compared to 401 g of Chemical Fertilizer (NPK Green 15:15:15) and 298 grams in control plants.

5. Discussion

The findings of this study showed that Pak Choy plants treated with food waste compost showed significantly better growth compared to chemical fertilizer and control treatments. The higher plant growth in food waste compost treatment was associated with balanced nutrient content and the effectiveness of compost in improving the physical and biological structure of the soil.

Reeza [1] and Ariffin *et al.*, [2], suggests that food waste compost has the potential to improve soil structure over time, though soil physical and biological parameters were not directly measured in this short-term study. This activity plays an important role in the process of decomposing organic matter, thus allowing plants to optimally absorb nutrients.

On the other hand, the exclusive use of chemical fertilizers, although providing immediate nutrients, tends to ignore the importance of good soil structure. This effect can be seen through less optimal growth compared to plants receiving organic compost. The findings of this study are consistent with the results of a study by Lee *et al.*, [7], which stated that Brassica plants benefit more when grown with organic fertilizers than chemical fertilizers, especially in terms of leaf and root growth.

The findings of this study also reflect the advantages of using food waste compost in sustainable urban waste management, as it can reduce pressure on landfills and reduce greenhouse gas emissions that usually result from the anaerobic decomposition process in landfills.

5.1 Limitations and Future Research Directions

While the results of this 30-day study indicate that food waste compost significantly improves the vegetative growth of *Brassica rapa chinensis* in terms of height, leaf count, and weight, several limitations must be acknowledged:

- i. **Study Duration and Scope:** The 30-day cultivation period focused exclusively on the initial growth phase. While sufficient for a fast-growing leafy vegetable like Pak Choy, this duration is too short to evaluate the long-term impact of organic amendments on soil fertility or cumulative plant health.
- ii. **Generalizability:** This experiment was conducted in a controlled greenhouse environment at Polytechnic Nilai. Consequently, the performance of the food waste compost under field conditions where variables such as pest pressure, leaching from heavy rain, and temperature fluctuations are present remain untested.
- iii. **Unmeasured Parameters:** Although literature suggests that compost improves soil structure and microbial activity, these specific biological and physical soil parameters were not measured in this study. Similarly, while environmental and economic benefits are hypothesized, a formal environmental impact assessment or cost-analysis was outside the current scope.
- iv. **Potential Risks:** The study did not account for the inherent variability of food waste compost. Unlike standardized chemical fertilizers like NPK 15:15:15, organic compost can vary in nutrient concentration and may pose risks of pathogen or heavy metal contamination if not properly stabilized. **Nutrient variability** depending on the source of the waste (e.g., household vs. industrial) and potential **pathogen or heavy metal contamination** if not processed at the correct temperature.

6. Updated Conclusion

This study demonstrates that food waste compost is an effective alternative to chemical fertilizers for the short-term growth of Pak Choy, yielding higher plant mass (420g) compared to NPK (401g). The compost supported a steady increase in leaf count and height, suggesting a sustained nutrient release. However, the wide-scale promotion of food waste compost requires further validation to address its variability and long-term effects. Future research should focus on:

- i. **Long-term Soil Health:** Conducting trials over multiple planting cycles to measure Soil Organic Matter (SOM) and microbial biomass.
- ii. **Field Trials:** Testing the compost in non-controlled environments to assess its resilience against environmental stressors.
- iii. **Safety and Standardization:** Performing heavy metal and pathogen testing across different batches of food waste to ensure safety for urban agriculture.
- iv. **Economic Analysis:** Comparing the production costs of composting versus the market price of synthetic fertilizers to quantify economic viability.

Future research should employ a **long-term longitudinal study** (6–12 months) to measure **Soil Organic Matter (SOM)** and **microbial biomass carbon**. Additionally, a **Heavy Metal Analysis** and **NPK variability test** on different batches of food waste compost are necessary to ensure safety and consistency for commercial use.

Acknowledgement

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