Synergistic Effects of Onion Biowaste and NPK Fertilizer on Productivity and Profitability of Pak Choi

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ABSTRACT

Applying inorganic fertilizer is essential for improving crop productivity. However, excessive usage of inorganic fertilizer may lead to soil acidification and have a substantial impact on plant development. The application of onion biowaste fertilizer with combination of NPK fertilizer on pak choi has been explored as a potential replacement for the use of fully inorganic fertilizer. This study investigated the effects of combining onion biowaste with NPK fertilizer on the productivity and profitability of pak choi (Brassica rapa var chinensis). The experiment was conducted in a greenhouse using a Randomized Complete Block Design (RCBD) with five treatments and five replications. The treatments used were T0 which is control (100% NPK fertilizer), T1 (100% peel onion fertilizer), T2 (50% NPK fertilizer + 50% peel onion fertilizer), T3 (30% NPK fertilizer + 70% peel onion fertilizer), and T4 (70% NPK fertilizer + 30% peel onion fertilizer). Yield parameters measured included fresh weight and biomass weight. Economic analysis was included gross margin, gross profit margin and benefit cost ratio. T2 and T3 produced the highest biomass weight with 185.00 g per plant and 170.30 g respectively. Concerning on economic analysis treatment T2 (50% NPK fertilizer + 50% peel onion fertilizer) consistently outperformed other treatment with gross profit margin of 58.54% compared with other treatment. These findings demonstrate that onion biowaste, when used in combination with NPK fertilizer, can effectively enhance plant performance while reducing reliance on inorganic fertilizers. This approach offers a sustainable and cost-effective alternative for small-scale farmers, promoting environmental benefits by reducing fertilizer-related pollution and utilizing household onion waste for agricultural use.

Keywords: Cost effective, economic, onion peel biowaste, pak choi, yield

INTRODUCTION

In modern agricultural systems, chemical fertilizers particularly NPK formulations (nitrogen, phosphorus, potassium) are widely used to enhance yields. Nitrogen facilitates vegetative growth, phosphorus supports root development and energy transfer, and potassium regulates water movement and stress tolerance. However, the benefits of these fertilizers come at a cost. Overapplication can cause several environmental and economic issues, including soil acidification, reduced soil fertility, disruption of microbial communities, and groundwater contamination due to nitrate and phosphate leaching [1,2]. Moreover, long-term overreliance on chemical fertilizers can lead to diminished ecosystem resilience, posing challenges to sustainable production systems. Despite mounting evidence of these adverse effects, many smallholder farmers may be unaware of the consequences or lack access to alternatives.

To address these concerns, integrated nutrient management strategies have gained traction, combining organic amendments with reduced rates of chemical fertilizers. Organic fertilizers derived from plant residues,

compost, manure, and other bio-wastes, improve soil structure, enhance microbial activity, and often contain beneficial micro- and macronutrients. These benefits contribute to improved soil fertility and long-term productivity. Recent reviews have highlighted the potential for integrating organic inputs into conventional farming systems as a pathway toward more resilient and sustainable agricultural practices.

Among the various sources of organic waste, onion peels commonly discarded during household food preparation or in restaurant operations represent a promising yet underutilized resource. Research has shown that onion biowaste is rich in calcium, phosphorus, potassium, sulphur compounds, and bioactive antioxidants [3]. Despite these valuable properties, onion waste is typically discarded, contributing to organic waste stream issues. Utilizing onion peels as an agricultural amendment offers multiple benefits: it provides a cost-effective nutrient source, supports waste reduction efforts, and aligns with circular economy principles. Previous study by [4], stated that the combination of crop ratio 50:50 revealed the best result on dry matter yield, and economic analysis in corn-soybean mixtures. Preliminary studies in other crop systems have indicated that onion peel extracts may enhance growth and yield, but these studies remain limited, especially regarding leafy vegetables like pak choi.

This study was designed to investigate the effects of different ratios of onion peel biowaste extract and NPK fertilizer on the yield and economic performance of pak choi under controlled greenhouse conditions. It focusing on the optimal combination of onion peel biowaste and NPK fertilizer that promotes maximum plant growth while reducing reliance on synthetic fertilizers and to reduce cost of production. It was hypothesized that treatments combining organic (onion peel biowaste extract) and inorganic (NPK) fertilizers would produce superior plant performance compared to treatments utilizing either fertilizer type alone. This anticipated outcome is attributed to the synergistic effects of nutrient availability and profitability associated with integrated fertilization strategies.

MATERIALS AND METHODS

The experiment was conducted at Greenhouse No. 1, Universiti Teknologi MARA (UiTM), Melaka Branch, Jasin Campus, situated in Merlimau, Melaka, Malaysia. The geographical coordinates of the site are 2°13'45.7"N latitude and 102°27'20.1"E longitude. The study was carried out over a period of three months, from August 2023 to December 2023. The growing medium employed in this study for the cultivation of pak choi consisted of a pre-formulated mixture of topsoil, sand, and organic matter in a volumetric ratio of 3:2:1, respectively.

A Completed Randomized Blocked Design (RCBD) with five treatments and five replications used in this experiment (Table 1). In the greenhouse, the polybags were organized according to their block. The total area used was 10 ft x 20 ft.

Table 1 Combination of onion peel biowaste and NPK fertilizer

Treatments	Description
T0	100% NPK fertilizer
T1	100% Peel onion fertilizer
T2	50% NPK fertilizer + 50% Peel onion fertilizer
T3	30% NPK fertilizer + 70% Peel onion fertilizer
T4	70% NPK fertilizer + 30% Peel onion fertilizer

To prepare the onion peel biowaste fertilizer, dried onion peels were collected. The peels were immersed in 1 liter of distilled water and placed in a clean, sealable jar. The jar was then stored in a shaded area at ambient temperature for 24 hours to allow sufficient extraction of soluble nutrients. Following the extraction period, the

mixture was filtered using a fine mesh strainer to separate the liquid extract from the solid residues. The resulting onion peel solution was transferred into a sterilized bottle and stored under hygienic conditions for subsequent use. The NPK fertilizer solution was prepared by diluting 2 millilitres of liquid foliar fertilizer in 1 liter of distilled water. All fertilizer treatments were formulated using 1.5-liter plastic bottles, which served as standardized containers for consistent application across treatments.

At the final harvest, a comprehensive assessment of yield-related parameters was conducted to evaluate the productivity and profitability of pak choi under different combination fertilizer treatments. The parameters measured included plant fresh weight and total biomass weight. These metrics are fundamental in determining the influence of treatment applications on plant health, nutrient uptake efficiency, and overall crop yield potential. Gross income was calculated by considering the economic yield based on the current field prices, which in the study (field price 1 kg pak choi= RM 2.50). Variable and fixed costs are always included the cost of seeds, fertilizers, pesticides, herbicides, labor and transportation, were calculated based on the local rates. Gross margin (GM) is generated by deducting the variable expenses from the gross income value. According to [5], the GM equation is specified in Eqs. 1:

$$GM = \text{Gross income} - \text{Variable cost} \quad (1)$$

Gross profit margin (GPM) is used to assess the financial health of pak choi production. The gross profit margin is most represented as a percentage of sales. GPM (Eqs. 2) was determined under the following formula:

$$GPM = \frac{\text{Gross income - Variable cost}}{\text{Gross income}} \times 100 \quad (2)$$

The benefit- cost ratio (BCR) is represented by the following formula as shown in Eqs. 3:

$$BCR = \frac{\text{Revenue}}{\text{Total cost of production}} \quad (3)$$

Data collected were analyzed using One-way Analysis of Variance (ANOVA) of Statistical Analysis System (SAS version 9.4; SAS Institute, Cary, NC). The means of the treatments found to be statistically significant were compared using the Least Significant Difference (LSD) test at the significance level of 0.05.

RESULTS AND DISCUSSION

Figure 2 presents the mean values of plant fresh weight and biomass yield for each treatment at the final harvest. Statistically significant differences ($P \leq 0.05$) were observed among the treatments for plant fresh weight. Treatment T2, which received a balanced mixture of 50% NPK fertilizer and 50% onion peel fertilizer, recorded the highest fresh weight at 158.76 grams. This was followed by T3 (30% NPK + 70% onion peel fertilizer), which produced a mean fresh weight of 136.48 grams. T4 (70% NPK + 30% onion peel fertilizer) and T0 (100% NPK) yielded 105.59 grams and 66.93 grams, respectively. The lowest fresh weight was recorded in T1 (100% onion peel fertilizer), with a mean of only 42.80 grams.

These findings align with the results [6], who reported that a balanced application of organic and inorganic fertilizers supports optimal plant growth. Organic fertilizers contribute valuable organic matter and micronutrients, which enhance soil structure and microbial activity, while inorganic fertilizers provide immediate nutrient availability that stimulates vegetative growth. The synergy between both fertilizer types ensures continuous nutrient supply and uptake efficiency, thereby enhancing fresh biomass production.

In contrast, reliance on a single fertilizer type, as seen in T1 and T0, may lead to suboptimal growth due to nutrient imbalances or deficiencies. Previous study noted that exclusive use of either organic or inorganic

fertilizers can result in stunted growth or reduced biomass accumulation, primarily due to incomplete or insufficient nutrient profiles during key developmental stages [7].

Table 2 Effect of onion biowaste and NPK fertilizer on yield productivity of Pak Choi

Treatment	Fresh yield plant^{-1} (g)	Biomass yield plant^{-1} (g)
T0 100% NPK fertilizer	66.93^{bc}	85.00^{bc}
T1 100% Peel onion fertilizer	42.80^{c}	68.32^{c}
T2 50% NPK fertilizer + 50% Peel onion fertilizer	158.76^{a}	185.00^{a}
T3 30% NPK fertilizer + 70% Peel onion fertilizer	136.48^{a}	170.30^{a}
T4 70% NPK fertilizer + 30% Peel onion fertilizer	105.59^{ab}	120.28^{b}

^{abc} Means within the same column followed by unlike letters are statistically significant ($P \leq 0.05$).

Statistically significant differences in biomass yield were observed among the treatments ($P \leq 0.05$). Treatment T2, which consisted of a balanced application of 50% NPK fertilizer and 50% onion peel fertilizer, recorded the highest mean biomass yield at 185.00 grams. This was followed by T3 (30% NPK + 70% onion peel fertilizer), which produced a mean of 170.30 grams. T4 (70% NPK + 30% onion peel fertilizer) ranked third, with a biomass weight of 120.28 grams. Meanwhile, T0 (100% NPK) and T1 (100% onion peel fertilizer) exhibited significantly lower biomass weights at 85.00 grams and 68.32 grams, respectively.

Synergistic effect of combining organic and inorganic fertilizer sources in enhancing plant biomass accumulation. The nutrient content and release characteristics of organic and inorganic fertilizers differ considerably; thus, combining the two ensures a more complete and balanced nutrient profile [8]. This balanced nutrient availability supports vital physiological and metabolic processes, such as photosynthesis and nutrient assimilation, which in turn contribute to greater overall plant biomass.

The superior performance of the integrated treatments (T2 and T3) suggests that a complementary interaction between the slow nutrient release from organic matter and the immediate nutrient availability from inorganic fertilizers plays a critical role in maximizing biomass production. Conversely, the limited nutrient spectrum or slow availability from a single-source fertilizer, as seen in T0 and T1, may not adequately support the plant's full developmental needs, resulting in reduced growth and lower biomass yield.

The gross income, cost of production, gross margin, gross profit margin and benefit-cost ratio are presented in Table 3. The maximum gross income was recorded in T2 (50% NPK fertilizer + 50% peel onion fertilizer) with RM 13720.56 ha^{-1} followed by combination of 30% NPK fertilizer + 70% peel onion fertilizer (T3) with RM 11453.70 ha$^{-1.}$ Next was T4 and T0 with RM 9450.40 ha^{-1} and RM 9057.00 ha^{-1} respectively. 100% Peel onion fertilizer (T1) gave the lowest gross income with RM 7890.50 ha^{-1}.

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In the present study, results revealed that combination of 50% NPK fertilizer + 50% peel onion fertilizer was most profitable with a higher gross margin (RM 8031.36 ha^{-1}) compared with other combination. A similar observation was made in other combination which 30% NPK fertilizer + 70% peel onion fertilizer and 70% NPK fertilizer + 30% peel onion fertilizer were recorded RM 6383.4 ha^{-1} and RM 3400.4 ha^{-1} respectively in higher gross margin compared to sole fertilizer.

Next, observation was also made for gross profit margin where the largest gross profit margin was produced from the T2 with 58.54%. Then, it was followed by T3 (55.73%). The least gross profit margin was obtained under sole NPK fertilizer (T0) with only 29.02%.

The benefit-cost ratio varied significantly between the treatment combination with 50% NPK fertilizer + 50% peel onion fertilizer having the highest value (2.41) followed by 30% NPK fertilizer + 70% peel onion fertilizer (2.26) whereas 100% NPK fertilizer (T0) had the lowest ratio with only 1.41. Therefore, if pak choi farmer smallholders choose to practice combination of 50% organic and 50% inorganic fertilizer, they could expect as high as RM 2.41 in benefits for each RM 1.00 costs of production.

Table 3 Effect of onion biowaste and NPK fertilizer on economic analysis (profitability) of Pak Choi

Treatment	Gross Income RM ha^{-1}	Cost of Production RM ha^{-1}	Gross Margin RM ha^{-1}	Gross Profit Margin (%)	Benefit-Cost Ratio (BCR)
T0 100% NPK fertilizer	9057.00	6427.90	2629.10	29.02	1.41
T1 100% Peel onion fertilizer	7890.50	4500.00	3390.50	42.96	1.75
T2 50% NPK fertilizer + 50% Peel onion fertilizer	13720.56	5689.20	8031.36	58.54	2.41
T3 30% NPK fertilizer + 70% Peel onion fertilizer	11453.70	5070.30	6383.4	55.73	2.26
T4 70% NPK fertilizer + 30% Peel onion fertilizer	9450.40	6050.00	3400.4	35.98	1.56

Where field price 1 kg pak choi = RM 2.50

(Date retrieved: 25th January 2024)

The result revealed that combination of 50% NPK fertilizer + 50% peel onion fertilizer was more profitable with a higher gross margin, gross profit margin and benefit-cost ratio compared to other treatment combinations. This might be due to the maximum yield obtained under this application and the optimum use of

inputs and labor with a consequent reduction in operating cost per unit of area. This result was supported by other authors [9,10] who found that combination organic and inorganic fertilizer was given higher economic benefits than sole fertilizer application.

Combining organic and inorganic fertilizers has shown synergistic effects in numerous crop systems. The organic fraction contributes humus-like compounds, improves soil aggregation, and supports beneficial microbial populations, while the mineral fertilizer component supplies readily available nutrients necessary for rapid growth. The hypothesized outcome is improved crop performance without sacrificing soil health or environmental quality. By incorporating onion peel biowaste into NPK fertilization schemes, researchers aim to achieve a similar synergistic benefit. This strategy could help smallholders maintain high yields while reducing their dependence on costly chemical fertilizers and minimizing negative environmental impacts.

CONCLUSION

In conclusion, this study demonstrated that the integration of organic and inorganic fertilizers, specifically the balanced application of 50% NPK fertilizer combined with 50% onion peel biowaste, produced the most favorable outcomes in terms of productivity and profitability of pak choi. The superior performance of these integrated treatments can be attributed to the synergistic effect of the nutrient composition. While NPK fertilizers provide a rapid and targeted supply of essential macronutrients namely nitrogen, phosphorus, and potassium the gradual decomposition of onion peel biowaste contributes beneficial micronutrients and organic matter, which help improve soil structure, microbial activity, and nutrient retention. This balanced nutrient availability supports optimal physiological and morphological development in pak choi, contributing to improved overall plant health and productivity.

Importantly, these findings underscore the potential of combining onion peel biowaste, an abundantly available agricultural waste product, with conventional fertilizers as a sustainable and eco-friendly strategy to reduce dependence on synthetic fertilizers and reduced cost of production with higher profitability. Overall, the integration of onion peel biowaste into fertilizer regimes presents a promising avenue for enhancing crop productivity, reducing agricultural input costs, and promoting environmental sustainability.

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CONFLICT OF INTEREST

The authors declares that there was no conflict of interest.

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