OnLine Journal of Biological Sciences

Original Research Paper

Growth Performance and Yield of *Brassica rapa* Var. Chinensis with Takakura and Conventional Compost

Kiew Vincent Wei Shuen and Mohd Effendi Wasli

Faculty of Resource Science and Technology, Universiti Malaysia Sarawak 94300, Kota Samarahan, Sarawak, Malaysia

Article history
Received: 02-11-2023
Revised: 09-01-2024
Accepted: 07-02-2024

Corresponding Author:
Kiew Vincent Wei Shuen
Faculty of Resource Science and Technology, Universiti Malaysia Sarawak 94300, Kota Samarahan, Sarawak, Malaysia
Email: vincentkiew0726@gmail.com

Abstract: Composted organic waste from food and plants is great for enhancing crop productivity and agricultural sustainability. However, the different composting methods produced by compost with home-based waste applied to growing media for crop growth remain a topic to discuss. Thus, the aim of this study is to evaluate the growth performance and yield of *Brassica rapa* var. chinensis (*B. rapa*) using different composting methods produced composts in growing media. This study is focused on the different composting methods produced compost on the growth performance and yield of *B. rapa* with or without additional chemical fertilizer for cultivation. Six different treatments were applied, namely topsoil (C), Takakura (T), conventional (M), and another 3 treatments (CF, TF, and MF) added with fertilizer. After six weeks of cultivation, the plant height averaged 20 cm with 18 leaves produced across compost amendment treatments, while the treatments with fertilizer with plant height averaged 25 cm with 21 leaves produced. The growth parameters, namely fresh-to-dry ratio, root-to-shoot ratio, and light interception percentage, showed no significant differences at $p \leq 0.05$ among all the compost amendment treatments (T, M, TF, and MF) while different with C and CF treatment. The leaf area and total yield of *B. rapa* show significant differences among compost amendment treatments, while the treatment with chemical fertilizer achieved the highest yield of 1173.4 cm^2 in leaf area and 44.3 t/ha of total yield. Using different composting methods produced compost, positively affects the growth performance of *B. rapa* plants. Meanwhile, combining fertilizer and compost amendment promotes *B. rapa* leaf area and yield.

Keywords: *Brassica rapa* Var. Chinensis (Pak Choy), Leafy Vegetable, Compost, Organic Amendment, Growth and Yield, Takakura Composting and Conventional Composting

Introduction

Bio-waste is defined as all biodegradable materials either from agriculture, post-harvest loss in farm or plantation, industrial, domestic activities, including kitchens, cafeterias, and restaurants (Chen *et al.*, 2017; Lim *et al.*, 2016; Abd Ghafar, 2017). According to Gustavsson *et al.* (2011) approximately 1.3 billion tonnes of food waste are produced globally. In Malaysia, it was reported that 15,000 tonnes of food were wasted daily, of which 3,000 tonnes were still suitable for consumption (Zin, 2018). Although waste disposal in landfills is an option for managing food waste in Malaysia, it has become increasingly challenging since many landfills have reached full capacity (Moh and Abd Manaf, 2014). Composting is one of the alternative methods that should be considered to meet the demand for new ways to manage waste from food production.

Compost is produced through a composting process which is a low-cost biological decomposition process that aids with the microbial activity that affects the physical chemicals of compost, including temperature, aeration, moisture content, C: N ratio, and pH (Kadir *et al.*, 2016). Even though composting is a timing process, its final product is proven to be the soil remediation that increases soil fertility and ecosystem activities. Additionally, composting has the potential to mitigate environmental pollution and greenhouse gas emissions by transforming the surplus food waste into a valuable soil amendment that enhances plant development. Applying compost amendment in agriculture increases the yield of crops (Farrell and Jones, 2009). According to Khalib *et al.* (2014), compost improves the soil's physical and biological properties, suppresses diseases caused by plant pathogens, and simultaneously reduces a significant amount of waste that would otherwise be directly disposed of at a landfill. Compost can be made from various organic materials, such as food scraps, yard waste, and weeds.

There are a few composting methods; one of the most common is conventional composting. Conventional or traditional composting is the bio-waste stacked layer by layer for naturally decomposing without microbe materials (Raimi *et al.*, 2020). At the same time, Takakura composting is currently the most popular method developed by Koji Takakura by producing fermentative microorganisms as compost seed, followed by mixing the fermented compost seed with the available bio-waste in residential areas (Nuzir *et al.*, 2019). The most exciting potential of the Takakura composting method is that it only requires a shorter time, about two weeks to complete the decomposition cycle compared with other composting methods that need months to complete (Nuzir *et al.*, 2019; Raimi *et al.*, 2020).

Few studies are available related to the composting method and ratio of starting material. Iqbal *et al.* (2010) have studied the effect of three different composting techniques (aerobic, anaerobic, and mixed type), while Guidoni *et al.* (2018) used three different ratios of home-based starting material (rice husk and raw fruit and vegetable leftover) for composting. However, the primary emphasis of both studies is placed on the consistency and maturity of compost. Compost use in growing media for crops is still an open question despite the preliminary research and information that has been gathered on various composting methods and different starting materials produced by compost. *Brassica rapa* var. chinensis, also known as Pak Choy or Bok Choi (Chinese mustard), is one of the common leafy vegetables that supply sufficient nutrients (Henny and Gobilik, 2022) and is commonly used in preliminary studies as it is easy to cultivate either farming or home gardening. Despite its ease of cultivation, the demand for *B. rapa*, a leafy vegetable, in Malaysia exceeds the local supply, necessitating imports (Maludin *et al.*, 2019). Home gardening with home compost is a fundamental option for self-consumption that can effectively alleviate this issue. Furthermore, there is a limitation of studies on the growth performance and yield of *B. rapa* when comparing compost produced through Takakura composting and conventional composting. Hence, it is worth investigating the effect of different composting methods (Takakura and conventional composting) produced compost on the growth performance of *B. rapa* var. chinensis crops.

Materials and Methods

Preparation of Home-Based Compost

The home-based waste used in this experiment was Fish Scraps (FS), Grass Clippings (GC), Banana Peel (BP), Coffee Ground (CG), Eggshells (ES) and Fallen Leaves (FL). The study used the Takakura method and the Conventional Method of composting. In Takakura composting, a compost seed was produced first from fermented solutions and fermented bed for 1 week following the Takakura method (Bobeck, 2010) in bins. Another composting method is the conventional composting method, in which the home-based waste is stacked layer by layer to form a heap in bins. The collected home-based waste materials are added based on the recommended brown (1 ES and 3 FL) to green (1 FS, 1 GC, 1 BP, and 1 CG) ratio of 1: 1 by Alves *et al.* (2019) in volume. The collected materials were composted naturally in a 20-gallon enclosed container with small holes for air circulation in an open environment at ambient conditions for 30 weeks at Kota Samarahan, Sarawak, Malaysia. All the compost piles in bins were turned in every 7 days intervals for air circulation. The physicochemical properties of Takakura and conventionally produced compost: pH range between 6.5-6.6 with electroconductivity range between 2700-3280 $\mu S\ cm^{-1}$. The nutrient of compost for Takakura and conventionally produced compost: Nitrogen (N) ranges between 1-2% with Phosphorus (P) ranging between 0.3-0.6% and Potassium (K) ranging between 0.5-1.5%.

Experimental Design and Husbandry

B. rapa seeds were sown in a plastic tray filled with coco peat for seedling establishment for approximately three (3) weeks. The seedlings of *B. rapa* were transplanted into poly pots using six (6) treatments with ten (10) replicates for each treatment, as presented in Table 1.

Table 1: The growing media used for planting *B. rapa* for each treatment

Treatment	Growing Media
Control (C)	Topsoil only
Control with Fertilizer (CF)	Topsoil with fertilizer*
Takakura (T)	Takakura compost amendment with topsoil
Takakura with Fertilizer (TF)	T Treatment with fertilizer application*
Conventional (M)	Conventional compost amendment with topsoil
Conventional with Fertilizer (MF)	C Treatment with fertilizer application*

*Amount of fertilizer application of 150 kg/ha or, at 2 g/pot (N: P: K 15: 15: 15) once standardized against surface area in the media pots according to the recommended rate for *B. rapa* cultivation by Maludin *et al.* (2019)

The *B. rapa* seedlings were then arranged in a greenhouse to receive full sunlight in a completely randomized design. The plants in the pots were irrigated with water twice a day. The growth experiment was conducted with compost to soil mix of 1:6. The general soil properties of the planting media used: Sandy clay loam soil (silt 10-30%; clay 20-30%; and sand 50-70%), pH (H_2O) ranged from 5.85-6.99, soil electroconductivity ranged between 120-970 µS cm^{-1}, C: N ratio ranged from 4.5-160.7. For fertilizer treatment plants, the fertilizer (NPK 15:15:15) was applied as a top dressing in the third week after transplants. The application of chemical fertilizer in the experiment mainly served as the positive control. In addition, the application of fertilizer is to test the growth of *B. rapa* either with the use of compost alone, fertilizer alone or with a combination of both compost and fertilizer. The crops were harvested after six (6) weeks after transplanting for further assessment.

Growth Performance Measurement of B. rapa

Plant height and the total number of leaves produced were recorded at seven (7) days until the plants entered a matured phase. The leaf area of the plants was measured using a leaf area meter. The light was measured using a light meter at the harvest stage of the *B. rapa*. The reading of the solar radiation above and below the canopy was taken and light interception was calculated using the formula (Portes and de Melo, 2014):

$$Light\ Interception\ (\%) = 1 - \frac{Light\ below\ canopy\ (Klux)}{Light\ above\ canopy\ (Klux)}$$

The weight of plants was measured with a weighing balance and recorded. The roots and shoots of plants period taken for each plant were immediately weighed and the value obtained was recorded before being dried in the oven for 72 h at a fixed temperature of 60°C in the oven; then, the plants were cooled at room temperature for dry weight measurement.

The formula used to calculate the fresh: Dry ratio was as follows:

$$Fresh\ weight\ to\ dry\ weight\ ratio = \frac{Fresh\ weight\ of\ plants\ (g)}{Dry\ weight\ of\ plants\ (g)}$$

The formula used to calculate the root: Shoot ratio was as follows:

$$Root\ to\ shoot\ ratio = \frac{Dry\ weight\ of\ root\ (g)}{Dry\ weight\ of\ shoot\ (g)}$$

Statistical Analysis

The collected data on all growth performance measurements of *B. rapa* is analyzed using Analysis of Variance (ANOVA) using IBM SPSS software version 25. Tukey post-hoc analysis was performed to separate the means at a 0.05 significance level. For each treatment, the standard error of the mean is reported.

Results and Discussion

Growth Performance of B. rapa with Compost

Table 2 shows the growth performance of *B. rapa* 6 weeks after transplanting to the potting media with different composting methods produced compost as compost amendment. All treatments applied with compost amendments (T and M) showed better growth performance than the control treatment (C). The plant height for *B. rapa* with compost amendment treatments is 20.0 cm and the number of leaves is an average of 18 per plant. Meanwhile, the leaf area in both compost amendments ranges from 466-504 cm^2. The fresh to dry ratio ranges from 9.19-9.75 and the root to shoot ratio averages 0.14. The light interception for both compost-to-soil ratios ranges from 59.2-61.0%. According to Kaleri *et al.* (2020), the Chinese cabbage (*B.* rapa) growth with compost-amended soil showed an improvement in plant growth in terms of plant height, leaf number, leaf area, fresh-dry ratio, and root-to-shoot ratio when compared to topsoil only. According to Bin Shuhaimi *et al.* (2019), a positive growth response when the tested plant was cultivated in media containing additional food waste compost. This was in contrast to the plants grown without additional compost. When comparing the growth performance of *B. rapa* to that of home-based compost, this study found that similar tendencies in plant growth were observed. Various studies have reported that the use of compost not only improves soil physical properties that enhance soil health but also improves soil properties that boost up growth and development of plants (Goldan *et al*., 2023; Cahyono *et al*., 2020; Wright *et al*., 2022). There might be rich nutrient content in the compost produced that is able to supply plant growth and development for a long period therefore reducing the use of chemical fertilizer (Goldan *et al*., 2023; Sánchez *et al*., 2017).

According to the result of root to root-to-shoot ratio obtained in Table 2, observable that the *B. rapa* treated with either T or M treatment performs a lower root-to-shoot ratio compared to control. The root-to-shoot ratio of plants is supposed to be a smaller value for better plant growth as the related increase of plant shoots or leaf area of plants (Bonifas *et al.*, 2005; De Oliveira and Viani, 2020; Lopez *et al.*, 2023) as there might have sufficient nutrient content in the compost produced from both T and M composting method with the home-based waste used in this study. Regarding *B. rapa* growth, the percentage of light interception of *B. rapa* has a higher percentage for the treatment of T and M compared with the control treatment. The compost added to the growing media might provide sufficient nutrients to *B. rapa* hence increasing in number of leaves and leaf area produced for each plant contributes to a higher light interception percentage (Eifediyi *et al.*, 2022; Ndzeshala *et al.*, 2023). The higher number of leaves produced and larger leaf area lead to higher light interception for more photosynthetic capacity (Eifediyi *et al.*, 2023) of *B. rapa* hence providing more production of crops.

Nevertheless, when the chemical fertilizer was added to *B. rapa* in the experiments with compost amendment (TF and MF), noticeable differences were observed between TF and MF in most plant growth. The plant height of *B. rapa* in TF and MF showed increment ranges of 24.4 cm to 26.1 cm, respectively. Meanwhile, the leaf area and total yield of *B. rapa* production for TF and MF treatments showed a double increment. Elfeel and Abohassan (2016) reported that the NPK fertilizer used for plants has a higher leaf area index value. The higher value of leaf area indicates higher plant weight that affects the results of yield obtained. According to Ouda and Mahadeen (2008), organic compost amendment used in *B. oleracea* (*Broccoli*) performed better in all growth assessments with additional compost and chemical fertilizer application. Similar studies by Liu *et al*. (2016) reported that the combined application of organic and inorganic fertilizers improved the yield and quality of *B*. *rapa*.

Moreover, regarding the compost produced by the composting method between Takakura composting (T) and conventional composting (M), the growth assessment of *B. rapa* shows no significant difference. Takakura composting uses a fermenting bed, which reduces composting time and increases plant growth parameters (Sharma *et al.*, 2017). Nonetheless, the results of this study could be attributed to aerobic composting because both composts were produced in bins with holes and the compost was turned weekly for aeration. Adediran *et al.* (2003) used two different partially aerated composting methods on two vegetable crops, showing similar effects on crop growth and improving yields. Moreover, the starting material ratio used in this study may also lead to the results obtained as no previous documentation was reported about the combination of home-based materials. The fish scraps added to the compost bins possibly contributed specific microbes and nutrients, resulting in an equal amount of beneficial microbes in both composting methods and no difference in plant growth assessment among the compost treatments in this study. According to Hepsibha and Geetha (2017), a study on the application of fish waste in *Vigna radiata* identified a high rhizobacterial and rhizobium population in liquid fish waste fertilizer and the microbial population's contents contribute to seed germination and root and shoot growth and development. Furthermore, the fish scraps collected for the compost pile in this study encompass not only the undesirable flesh of the fish but also its organs such as gills and intestines. It is believed that these fish organs contain specific beneficial microorganisms and fish protein (Ahuja *et al*., 2020), which enhance the quality of the compost. Consequently, the resulting end product contributes to the improved growth performance of *B. rapa* plants in this study. The produced compost is used for home gardening, especially for horticulture, and currently expands in crop planting for self-consumption. In addition, home-based waste is usually collected and composted in the yard or garden at home area without any testing or analysis of its nutrient content. Chang *et al.* (2023) reported that the chemical and biological analysis of compost can be time-consuming and costly and it would be difficult to determine the nutrient after one cycle of compost production since the nutrients largely depend on the source of materials used. In the case of home farming, it is targeted to grow clean and safe crops for daily consumption and, most importantly, to produce sufficient yield for one household. If using home-made compost is a viable alternative that is also effective, this would reduce the dependence of home gardening on inorganic fertilizers that are effective for crop production. In this study, the home farming simulations were carried out for preliminary testing of the home-based waste on *B*. *rapa* growth with different composting methods.

Table 2: Growth assessment of *Brassica rapa* var. chinensis (Pak Choy) for all treatments

	Treatment without fertilizer			Treatment with fertilizer		
Growth assessment	C	T	M	CF	TF	MF
Plant height (cm)	11.1±1.1^{a}	20.0±1.3^{bc}	20.5±1.8^{bcd}	18.2±6.4^{b}	24.4±1.9^{cd}	26.1±1.2^{d}
No. of leaves	9±1^{a}	18±2^{b}	18±3^{b}	12±3^{a}	21±1b	22±1^{b}
Leaf area (cm^2)	119±50^{a}	466±125^{bc}	504±38^{c}	288±121^{ab}	1041±105^{d}	1173±114^{d}
Fresh: Dry ratio	8.35±2.28^{a}	9.47±2.32^{ab}	9.19±1.62^{ab}	11.45±2.60^{ab}	12.61±1.95^{ab}	13.31±2.95^{b}
Root: Shoot ratio	0.36±0.09^{b}	0.14±0.05^{a}	0.13±0.03^{a}	0.15±0.13^{a}	0.11±0.04^{a}	0.11±0.04^{a}
Light interception (%)	29.8±7.0^{a}	59.2±5.6^{b}	61.0±14.0^{b}	57.6±13.4^{b}	75.2±9.5^{b}	76.00±5.8^{b}
Total yield production (t/ha)	1.7±0.9^{a}	18.1±4.9^{c}	16.5±1.2b^{c}	6.6±2.8a^{b}	41.3±8.9^{d}	44.30±8.1^{d}

*Means ± standard deviation. All data presented are on an average basis per plant. The different letter indicates significant differences among treatments at 5% using Tukey's test ($p<0.05$). C: Topsoil only (control), T: Takakura compost amendment, M: Conventional compost amendment, CF: Topsoil (control) + fertilizer, TF: Takakura compost amendment + fertilizer and MF: Conventional compost amendment + fertilizer

Yield Production of B. rapa with Compost

According to the DOA (2022), the statistic of *B. rapa* production yield for the year 2020-2021 is 13.9 t/ha. Figure 1, the combination of fertilizer and compost amendment with compost to soil (TF and MF) showed better yield than control treatment and other compost amendments without chemical fertilizer with double yield production. Such conditions indicated that the cooperation of chemical fertilizer and compost amendment is needed for rapid nutrient uptake of *B. rapa*. Moreover, the compost amendment treatments without fertilizer treatments (T and M) still achieved the recommended yield proposed by DOA with a total mean yield of 18.1 and 16.5 t/ha, respectively. Consequently, the designed starting material and the composting method used to produce the compost for this study suit the growth of the *B. rapa* crop.

For *B. rapa* crops growing, the essential agronomic factors are the number of leaves, leaf area, and plant yield (Nasution *et al.*, 2021). Overall, the experiment for different composting methods (T and M) produced compost as an amendment for *B. rapa* growing, showing almost similar data collection for all parameters. In contrast, the fertilizer applied for both treatments (TF and MF) had a double increment in leaf area and plant weight. The incorporation of compost amendment and fertilizer in agriculture could help improve crop yield and quality (Khan *et al.*, 2017).

Besides the composting method, the compost used may affect the results. For example, compost made from different materials may have other nutrient profiles. According to Parwada *et al.* (2020), the different types of manure compost used show different total dry matter production of Baby Spinach growth, whereas the poultry manure compost performs better results while the use of fertilizer shows better total dry production than cattle manure compost. Another study by Nursuhaida *et al.* (2022) stated that microbial compost on *B. rapa* obtained the highest fresh weight during harvest compared with vermicompost, biochar compost, and fertilizer. The studies conducted by Parwada *et al.* (2020); Nursuhaida *et al.* (2022) both examine the use of manure compost. In contrast, the present study investigates the use of home-based waste compost to promote the growth of *B. rapa*. The results indicate that the growth of *B. rapa* was significantly better in the home-based waste compost treatment compared to the control treatment.

Nevertheless, there is still limited information that demonstrates comparable outcomes when examining compost composed of various materials. According to Prado (2014), there is no significant difference in the growth assessment of *B. rapa* when using vermicompost, conventional compost, or fertilizer. In their study, Uwumarongie-Ilori *et al.* (2012) found no substantial difference in the vegetative growth of oil palm seedlings when using compost made from empty fruit bunches, poultry, or cattle manure. Although neither study found a substantial difference in the compost used for crop growth, compost is still recommended because it helps reduce the over-application of inorganic fertilizer during cultivation. Furthermore, the use of compost will employ long-term practices that will improve soil health and reduce reliance on chemical fertilizers (Nursuhaida *et al.*, 2022). Overall, the yield of *B. rapa* grown with the cooperation of compost and fertilizer either Takakura or conventional composting produced compost shows significant differences among all treatments with approximately 43.0 t/ha, while the treatments of T and M show a significant difference to control treatment with an average of 17.0 t/ha. Even though the CF treatment shows no significance with M treatments, based on the mean yield (Fig. 1), the M treatments show approximately 2.5 times more yield than CF treatments. This indicates that the use of compost only either Takakura or conventional composting produced compost with selected home-based waste is for *B. rapa* growth and performs better results when it is cultivated in combination with fertilizer.

Compost maturity could additionally affect crop growth and yield. Immature compost produced from nitrogen-rich material may contain high levels of ammonium, resulting in low compost pH and high electroconductivity, which is phytotoxic to crop growth (Ko *et al.*, 2008; Phonsuwan *et al.*, 2016). According to Phonsuwan *et al.* (2016), immature compost results in poor plant growth of lettuce. In addition, Russell *et al.* (2022) noted that the use of immature compost stunned lettuce germination. Although the maturity of the compost in this study is only determined by chemical parameters such as pH, electric conductivity, and C: N ratio, further research should be conducted to determine the biological parameters that determine compost maturity.

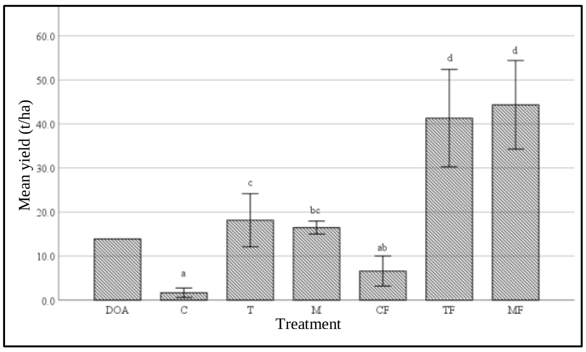

Fig. 1: Total yield of *B. rapa* for all treatments; *Different letter indicates significant differences among treatments at 5% using Tukey's test ($p<0.05$). DOA: Department of Agriculture, Malaysia suggested yield for *B. rapa*, C: Topsoil only (control), T: Takakura compost amendment, M: Conventional compost amendment, CF: Topsoil (control) + fertilizer, TF: Takakura compost amendment + fertilizer and MF: Conventional compost amendment + fertilizer

The application rate of compost influences the growth performance of plants. Previous studies by Tsegaye (2019) examined the effect of different rates of compost application on the growth of carrots, with the results indicating that increasing the compost application rate from 0-75 t/ha nearly tripled the vegetative growth of carrots. Izilan *et al*. (2022) conducted a similar study on Choy Sum and found that increasing the biochar compost application rate increased the biomass of Choy Sum. Aji *et al*. (2021) reported similar results in which the biomass of dwarf crape jasmine increased when the amount of applied compost was increased from 0-20%. Despite this, Aji *et al*. (2021) found that increasing compost application from 30-100% decreased dwarf crape jasmine biomass. When an excessive amount of compost is applied, it is not necessarily beneficial to crop growth and yield; consequently, it is essential to prioritize the optimal amount of compost added to achieve optimal nutrient management.

Given that excessive chemical fertilizer application can be harmful to the environment (Kumar *et al.*, 2019), compost can be a more sustainable alternative or supplementary material to reduce the amount of chemical fertilizer applied for crop production (Kizito *et al*., 2019). Although it may be challenging to produce a consistently effective compost in enhancing crop growth and yield, compost is a natural product that can be produced from home waste, making it a more sustainable option for improving crop growth performance and yield, particularly for *B. rapa*.

Conclusion

The analysis in this experiment shows that using different composting methods either Takakura composting or conventional composting produced compost with selected home-based waste for preliminary study of *B. rapa*, positively affects the growth performance of *B. rapa* plants. In addition, it is proven that using fertilizer enhances *B. rapa* plants while combining fertilizer and compost amendment promotes *B. rapa* yield. Based on the experiment outcomes, although the parameters between T and M compost amendment treatments show no significant effect on growth performance, the M compost amendment performed better growth performance and yield for *B. rapa*. However, certain aspects should be revisited, particularly the current ratio of both Takakura and conventional compost, for consistent observation regarding the different ratios of compost added to growing media for *B. rapa* growth. The use of organic fertilizers like compost helps enhance plant growth. Therefore, it is advisable to utilize a combination of compost amendment and chemical fertilizer for home farming. This approach, specifically when applied to small areas and small pots, has demonstrated the most favorable growth performance and yield. Composting can effectively decrease the overall waste volume in the environment while simultaneously promoting plant growth. Additionally, utilizing compost derived from household waste serves the dual purpose of both facilitating production and enabling individuals to cultivate their own clean and safe food at home.

Acknowledgment

The authors would like to thank the Universiti Malaysia Sarawak for providing the facilities to conduct the experiments.

Funding Information

The study was self-funded by the authors. The author would like to thank Universiti Malaysia Sarawak for their support in accommodating the research facilities in conducting this study.

Author’s Contributions

Kiew Vincent Wei Shuen: Participated in all experiments, coordinated the data analysis and contributed to the written of the manuscript.

Mohd Effendi Wasli: Designed the research and planned and organized the study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

References

Abd Ghafar, S. W. (2017). Food waste in Malaysia: Trends, current practices and key challenges. *Centre of Promotion Technology, MARDI, Persiaran MARDI-UPM*.

Adediran, J. A., Taiwo, L. B., & Sobulo, R. A. (2003). Effect of organic wastes and method of composting on compost maturity, nutrient composition of compost and yields of two vegetable crops. *Journal of Sustainable Agriculture*, *22*(4), 95-109. https://doi.org/10.1300/J064v22n04_08

Ahuja, I., Dauksas, E., Remme, J. F., Richardsen, R., & Løes, A. K. (2020). Fish and fish waste-based fertilizers in organic farming with status in Norway: A review. *Waste Management*, *115*, 95-112. https://doi.org/10.1016/j.wasman.2020.07.025

Aji, N. A. S., Yaser, A., Lamaming, J., Ugak, M. A. M., Saalah, S., & Rajin, M. (2021). Production of food waste compost and its effect on the growth of dwarf crape jasmine. *J. Kejuruter*, *33*(3), 413-424. https://doi.org/10.17576/jkukm-2021-33(3)-04

Alves, T. L., Lemos, E. F., Barbosa, J. D. A., De Almeida, G. M., & Bertino, A. M. P. (2019). Proportions of Organic Waste in the Process of Composting. *Agriculture and Food Sciences Research, 6*(1), 15-21. https://doi.org/10.20448/journal.512.2019.61.15.21

Bin Shuhaimi, S. A. D. N., Kanakaraju, D., & Nori, H. (2019). Growth performance of roselle (*Hibiscus sabdariffa*) under application of food waste compost and Fe_3O_4 nanoparticle treatment. *International Journal of Recycling of Organic Waste in Agriculture*, *8*, 299-309. https://doi.org/10.1007/s40093-019-00302-x

Bobeck, M. (2010). Organic Household Waste in Developing Countries: An overview of environmental and health consequences and appropriate decentralised technologies and strategies for sustainable management.

Bonifas, K. D., Walters, D. T., Cassman, K. G., & Lindquist, J. L. (2005). Nitrogen supply affects root: Shoot ratio in corn and velvetleaf (Abutilon theophrasti). *Weed Science*, *53*(5), 670-675. https://doi.org/10.1614/WS-05-002R.1

Cahyono, P., Loekito, S., Wiharso, D., Rahmat, A., Nishimura, N., & Senge, M. (2020). Effects of Compost on Soil Properties and Yield of Pineapple (*Ananas comusus*L. Merr.) On Red Acid Soil, Lampung, Indonesia. *Geomate Journal*, *19*(76), 33-39. https://doi.org/10.21660/2020.76.87174

Chang, Y. T., Lee, C. H., Hsieh, C. Y., Chen, T. C., & Jien, S. H. (2023). Using fluorescence spectroscopy to assess compost maturity degree during composting. *Agronomy*, *13*(7), 1870. https://doi.org/10.3390/agronomy13071870

Chen, H., Jiang, W., Yang, Y., Yang, Y., & Man, X. (2017). State of the art on food waste research: A bibliometrics study from 1997-2014. *Journal of Cleaner Production*, *140*, 840-846. https://doi.org/10.1016/j.jclepro.2015.11.085

De Oliveira, A. C. C., & Viani, R. A. G. (2020). Sewage sludge organic fertilizer as a promoter of initial growth of Euterpe edulis Mart., an endangered palm. *International Journal of Recycling Organic Waste in Agriculture*, *9*(2), 161-170. https://doi.org/10.30486/IJROWA.2020.1890190.1020

DOA. (2022). Vegetable and Cash Crops Statistics. *Department of Agriculture*, *Malaysia*.

Eifediyi, E. K., Ahamefule, H. E., Ogedegbe, F. O., Agbede, T. M., Kareem, I., & Ajayi, A. D. (2023). Influence of Tithonia diversifolia and cattle manures on the growth and yield of sesame (*Sesamum indicum* L.). *International Journal of Recycling Organic Waste in Agriculture*, *12*(3), 291-303. https://doi.org/10.30486/IJROWA.2022.1945769.1377

Eifediyi, E. K., Imam, A. Y., Ahamefule, H. E., Ogedegbe, F. O., & Isimikalu, T. O. (2022). Influence of sawdust biochar application on the growth, morphological characters and yield of four varieties of sesame (*Sesamum indicum* L.). *International Journal of Recycling Organic Waste in Agriculture*, *11*(2), 189-200. 200. https://doi.org/10.30486/IJROWA.2021.1933189.1274

Elfeel, A. A., & Abohassan, R. A. (2016). Compost effects on leaf area index and seed production enhancement in an important arid land leguminous tree (*Acacia tortilis* subsp. Raddiana). *Legume Research-An International Journal*, *39*(5), 748-754. https://doi.org/10.18805/lr.v0iOF.3546

Farrell, M., & Jones, D. L. (2009). Critical evaluation of municipal solid waste composting and potential compost markets. *Bioresource Technology*, *100*(19), 4301-4310. https://doi.org/10.1016/j.biortech.2009.04.029

Goldan, E., Nedeff, V., Barsan, N., Culea, M., Panainte-Lehadus, M., Mosnegutu, E., ... & Irimia, O. (2023). Assessment of Manure Compost Used as Soil Amendment a Review. *Processes*, *11*(4), 1167. https://doi.org/10.3390/pr11041167

Guidoni, L. L. C., Marques, R. V., Moncks, R. B., Botelho, F. T., da Paz, M. F., Corrêa, L. B., & Corrêa, É. K. (2018). Home composting using different ratios of bulking agent to food waste. *Journal of Environmental Management, 207*, 141-150. https://doi.org/10.1016/j.jenvman.2017.11.031

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R. & Meybeck, A. (2011). Global Food Losses and Food Waste: Extent Causes and Prevention. *Food and Agriculture Organization (FAO) of the United Nations Rome*. ISBN: 978-92-5-107205-9.

Henny, R. L., & Gobilik, J. (2022). Overview on leafy (Pak Choy) vegetable industry and vertical soilless culture application for Pak Choy production in Malaysia. *Transactions on Science and Technology*, *9*(4), 204-222. https://tost.unise.org/pdfs/vol9/no4/ToST-9x4x204-222xRA.pdf

Hepsibha, B. T., & Geetha, A. (2017). Effect of fermented fish waste (Gunapaselam) application on the soil fertility with special reference to trace elements and the growth characteristics of Vigna radiata. *Int. J. Agric. Innov. Res.*, *5*, 607-613. https://ijair.org/administrator/components/com_jresearch/files/publications/IJAIR_2237_FINAL.pdf

Iqbal, M. K., Shafiq, T., & Ahmed, K. (2010). Effect of different techniques of composting on stability and maturity of municipal solid waste compost. *Environmental Technology*, *31*(2), 205-214. https://doi.org/10.1080/09593330903426703

Izilan, N. I. S., Sari, N. A., Othman, N. M. I., & Mustaffha, S. (2022, July). The effects of biochar-compost on soil properties and plant growth performance grown in a sandy-loam soil. *In IOP Conference Series: Earth and Environmental Science* (Vol. *1059*, No. 1, p. 012021). IOP Publishing. https://doi.org/10.1088/1755-1315/1059/1/012021

Kadir, A. A., Azhari, N. W. & Jamaludin, S. N. (2016). An Overview of Organic Waste in Composting. *In MATEC Web of Conferences, EDP Sciences, 47*(05025): 1-5. https://doi.org/10.1051/matecconf/20164705025

Kaleri, A. R., Ma, J., Jakhar, A. M., Hakeem, A., Ahmed, A., Napar, W. P. F., ... & Kaleri, A. H. (2020). Effects of dung beetle-amended soil on growth, physiology and metabolite contents of Bok Choy and improvement in soil conditions. *Journal of Soil Science and Plant Nutrition*, *20*, 2671-2683. https://doi.org/10.1007/s42729-020-00333-8

Khalib, S. N. B. B., Azura, Z. I., & Nuraiti, T. T. (2014). Mini Review: Environmental Benefits of Composting Organic Solid Waste by Organic Additives. *Bulletin of Environmental Science and Sustainable Management (e-ISSN 2716-5353)*, *2*(1), 1-7. https://doi.org/10.54987/bessm.v2i1.40

Khan, A. A., Hamida Bibi, H. B., Zahid Ali, Z. A., Muhammad Sharif, M. S., Shah, S. A., Haroon Ibadullah, H. I., ... & Sajid Ali, S. A. (2017). Effect of compost and inorganic fertilizers on yield and quality of tomato. https://www.cabidigitallibrary.org/doi/full/10.5555/20193305768

Kizito, S., Luo, H., Lu, J., Bah, H., Dong, R., & Wu, S. (2019). Role of nutrient-enriched biochar as a soil amendment during maize growth: Exploring practical alternatives to recycle agricultural residuals and to reduce chemical fertilizer demand. *Sustainability*, *11*(11), 3211. https://doi.org/10.3390/su11113211

Ko, H. J., Kim, K. Y., Kim, H. T., Kim, C. N., & Umeda, M. (2008). Evaluation of maturity parameters and heavy metal contents in composts made from animal manure. *Waste Management*, *28*(5), 813-820. https://doi.org/10.1016/j.wasman.2007.05.010

Kumar, R., Kumar, R., & Prakash, O. (2019). Chapter-5 the impact of chemical fertilizers on our environment and ecosystem. *Chief Ed*, *35*, 69.

Lim, W. J., Chin, N. L., Yusof, A. Y., Yahya, A., & Tee, T. P. (2016). Food waste handling in Malaysia and comparison with other Asian countries. *International Food Research Journal*, *23*, S1.

Liu, H., Wang, H., Yang, D., He, N., & Liu, M. (2016, January). Effects of combined application of organic and inorganic fertilizers on yield and quality of Chinese cabbage. In *2016 International Forum on Management, Education and Information Technology Application* (pp. 82-85). Atlantis Press. https://doi.org/10.2991/ifmeita-16.2016.16

Lopez, G., Ahmadi, S. H., Amelung, W., Athmann, M., Ewert, F., Gaiser, T., ... & Seidel, S. J. (2023). Nutrient deficiency effects on root architecture and root-to-shoot ratio in arable crops. *Frontiers in Plant Science*, *13*, 5385. https://doi.org/10.3389/fpls.2022.1067498

Maludin, A. J., Nur Aisar, I. C. M., Silip, J. J., Yap, Y. F., & Gobilik, J. (2019). Effects of dairy farm effluent compost on growth and yield of pak choy (*Brassica rapa* L.) in pot system. *Transactions on Science and Technology*, *6*(2-2), 272-282. https://tost.unise.org/pdfs/vol6/no2-2/6x2-2x272-282.pdf

Moh, Y. C., & Abd Manaf, L. (2014). Overview of household solid waste recycling policy status and challenges in Malaysia. *Resources, Conservation and Recycling*, *82*, 50-61. https://doi.org/10.1016/j.resconrec.2013.11.004

Nasution, I. S., Satriyo, P., Yolanda, S., & Alma, A. (2021). Non-destructive measurement of leaf area and leaf number of hydroponic pak-choy plants (*Brassica rapa*). In *IOP Conference Series: Earth and Environmental Science* (Vol. *644*, No. 1, p. 012004). IOP Publishing. https://doi.org/10.1088/1755-1315/644/1/012004

Ndzeshala, S. D., Obalum, S. E., & Igwe, C. A. (2023). Some utilisation options for cattle dung as soil amendment and their effects in coarse-textured Ultisols and maize growth. *International Journal of Recycling Organic Waste in Agriculture*, *12*(1), 123-139. https://doi.org/10.30486/IJROWA.2022.1934239.1284

Nursuhaida, M., Faizah, A. K., Norhanizan, U., Azimah, H. and Shah, S. Z. (2022). Effects of Organic Fertilizer on Growth Performane and Postharvest Quality of Pak Choy (*Brassica rapa* subsp. Chinensis L.). *Agrotech- Food Science, Technology and Environment*, *1*, (1), 43-50. https://doi.org/10.53797/agrotech.v1i1.6.2022

Nuzir, F. A., Hayashi, S., & Takakura, K. (2019). Takakura composting method (TCM) as an appropriate environmental technology for urban waste management. *International Journal of Building, Urban, Interior and Landscape Technology (BUILT)*, *13*, 67-82. https://doi.org/10.14456/built.2019.6

Ouda, B. A., & Mahadeen, A. Y. (2008). Effect of fertilizers on growth, yield, yield components, quality and certain nutrient contents in broccoli (*Brassica oleracea*). *International Journal of Agriculture and Biology*, *10*(6), 627-632.

Parwada, C., Chigiya, V., Ngezimana, W., & Chipomho, J. (2020). Growth and performance of baby spinach (*Spinacia oleracea* L.) grown under different organic fertilizers. *International Journal of Agronomy*, *2020*, 1-6. https://doi.org/10.1155/2020/8843906

Phonsuwan, M., Lee, M. H., Moon, B. E., Kim, Y. B., Kaewjampa, N., Yoon, Y. C., & Kim, H. T. (2016). Effect of immature compost on available nutrient capability and heavy metal accumulation in soil for lettuce (*Lactuca sativa* L.) cultivation. *Journal of Bio-Environment Control*, *25*(4), 343-350. https://doi.org/10.12791/KSBEC.2016.25.4.343

Portes, T. D. A., & Melo, H. C. D. (2014). Light interception, leaf area and biomass production as a function of the density of maize plants analyzed using mathematical models. *Acta Scientiarum. Agronomy*, *36*, 457-463. https://doi.org/10.4025/actasciagron.v36i4.17892

Prado, A. J. (2014). Effect of organic fertilizer on the growth performance of *Brassica rapa* under La Union, Philippines. *E-International Scientific Research Journal*, *5*(4), 1-6.

Raimi, M. H. S., Ismail, T. T. N. H., Najib, M. M. Z. and Yusop, M. F. (2020). Food Waste Solution at Home: Conventional and Rapid Composting Technique. *Food Research 4*, (6), 1-10. https://doi.org/10.26656/fr.2017.4(S6).016

Russell, J., Stutte, G. W., & De Leon, P. (2022, July). Evaluation of Candidate Crop Plant Lactuca Sativa in Biologically Enhanced Martian Regolith. 51st *International Conference on Environmental Systems*. https://ttu-ir.tdl.org/items/e95583e1-2479-4ff7-8fbf-322361dc0115

Sánchez, Ó. J., Ospina, D. A., & Montoya, S. (2017). Compost supplementation with nutrients and microorganisms in composting process. *Waste Management*, *69*, 136-153. https://doi.org/10.1016/j.wasman.2017.08.012

Sharma, A., Saha, T. N., Arora, A., Shah, R., & Nain, L. (2017). Efficient microorganism compost benefits plant growth and improves soil health in Calendula and Marigold. *Horticultural Plant Journal*, *3*(2), 67-72. https://doi.org/10.1016/j.hpj.2017.07.003

Tsegaye, K. Z. B. (2019). Effect of Different Rates of Compost Application on Growth Performance and Yield Components of Carrot (*Daucus carrota* L.) in Gurage Zone, Ethiopia. https://doi.org/ 10.7176/JAAS/54-03

Uwumarongie-Ilori, E. G., Sulaiman-Ilobu, B. B., Ederion, O., Imogie, A., Imoisi, B. O., Garuba, N., & Ugbah, M. (2012). Vegetative growth performance of oil palm (*Elaeis guineensis*) seedlings in response to inorganic and organic fertilizers. *Greener J. Agric. Sci*, *2*, 26-30. https://doi.org/10.15580/GJAS.2013.3.1220

Wright, J., Kenner, S., & Lingwall, B. (2022). Utilization of compost as a soil amendment to increase soil health and to improve crop yields. *Open Journal of Soil Science*, *12*(6), 216-224. https://doi.org/10.4236/ojss.2022.126009

Zin, N. M., Saim, M., & Suhaimi, A. H. M. S. (2018). Household food wastage prevention in Malaysia: An issue processes model perspective. *Econ. Technol. Manag. Rev*, *13*, 51-62. http://etmr.mardi.gov.my/Content/ETMR%20Vol.13(2018)/Vol13_5.pdf