Volume 13, Issue 3, 132428 (1-8)

International Journal of Recycling Organic Waste in Agriculture (IJROWA)

https://dx.doi.org/10.57647/j.ijrowa.2024.1303.28

Efficacy of vermicompost derived from local organic wastes as nursery substrates for cabbage and chili seedlings

Haruthai Thaisuchat[1], Purepan Panikanan[2], Jumnian Meesumlee[2]*

[1]*Faculty of Science, Lampang Rajabhat University, Lampang, Thailand.*
[2]*Faculty of Agricultural Technology, Lampang Rajabhat University, Lampang, Thailand.*

*Corresponding author: jumnian_w@g.lpru.ac.th

Original Research

Received:
9 May 2023
Revised:
18 August 2023
Accepted:
23 December 2023
Published online:
15 January 2024

Abstract:

Purpose: This study aimed to evaluate vermicompost derived from various local organic wastes as a nursery material for cultivating cabbage and chili seedlings, converting organic waste into fertilizer through vermicomposting.

Method: Local organic materials, including cow dung, spent mushroom waste, and coffee grounds were utilized as the main substrates for earthworm bedding. Three main substrates, one additive (white popinac leaves), and various combinations of these materials were processed, resulting in a total of 10 methods. After two months of composting, all vermicompost was analyzed for N, P, and K content before being used as nursery material for seedling production of cabbage (*Brassica oleracea*) and chili (*Capsicum annuum*). A commercial nursery material was used as a control.

Results: The results revealed a significant difference between vermicompost with bedding derived from different organic materials and N P K content. After 4 weeks of plant germination, plant height, leaf width, leaf length, and the number of leaves of cabbage showed the greatest in treatment with vermicompost 8 (cow dung: spent mushroom waste: white popinac leaves) followed by vermicompost 4 (cow dung: spent mushroom), which showed comparable results to the commercial nursery material. A negative effect on chili seedling growth was found in some treatments.

Conclusion: The study concluded that cow dung proved to be an excellent material for use as a bedding substrate and earthworm feed. Vermicompost produced from a combination of cow dung and spent mushroom waste, or supplemented with white popinac leaves, can effectively serve as a nursery material for cabbage seedlings.

Keywords: Vermicompost; Cow dung; Spent mushroom waste; Coffee grounds; Seedling

1. Introduction

Recent research has shown that vermicompost, a nutrient-rich organic material produced through the decomposition of organic matter by earthworms, plays a vital role in enhancing soil fertility and plant growth productivity (Pierre-Louis et al., 2021; Rehman et al., 2023). It achieves this through several mechanisms: including enhancing soil organic matter content, reducing soil bulk density, improving water and mineral nutrient availability, exhibiting hormone-like effects, and reducing the effects of pests and pathogens. Nurhidayati et al. (2018) reported that vermicompost application enhanced soil N P K content and increased mustard (*Brassica rapa* L.) yield. Vermicompost derived from cow dung had a positive impact on nutrient cycles, notably increasing soil total nitrogen by 18% and soil organic carbon by 31% (Raza et al., 2023). According to Shen et al. (2022), the application of vermicompost reduced the bulk density, electrical conductivity, and pH of salt-affected mudflat soil, while increasing its organic carbon, nitrogen, and phosphorus contents. Through a meta-analysis, Ma et al. (2022) observed that vermicompost significantly improved the water-holding porosity of the growing medium by 25.3%. There is evidence that plant growth was significantly enhanced in plants treated with 50% vermicompost compared to those treated with GA and IAA (Rekha et al., 2018). Plant hormones, such as cytokinins, gibberellins, and auxins, can be found in vermicompost (Ruangjanda et al., 2022). It is reported that microbial inhibition during vermicomposting results from the enzymatic actions of earthworms in their intestines and the secretion of antibacterial agents (Swati and Hait, 2018). The use of vermicompost to improve soil quality, increase growth rates, and enhance crop yields has been studied in various plant species, including marigold (Gupta et al., 2014), maize, millet, and sorghum (Esteves et al., 2020), cucumber (Wang et al., 2021), lettuce (Schröder et al., 2021), Indian spinach (Das et al., 2022), lavender (Sharafabad et al., 2022), as well as wheat and maize (Raza et al., 2023).

Many organic wastes generated by human society are often disposed of in landfills or possibly by incineration, creating substantial economic and environmental problems. Organic wastes, including agricultural residues, animal manure, and industrial wastes, require sustainable waste management. One useful method for biowaste recycling is vermicomposting, where the action of earthworms degrades the organic matter. A large variety of organic wastes can be used in the vermicomposting process. Animal waste, especially cattle manure, was often used as the main substrate for earthworm culture (Singh et al., 2020b; Alipour et al., 2023; Syarifinnur et al., 2022; Raza et al., 2023). Household solid waste and market organic waste, consisting of various fruits and vegetable residues, were good resources for vermicompost preparation (Gupta et al., 2014; Joshi et al., 2015; Liégui et al., 2021; Syarifinnur et al., 2022). Coffee grounds and straw pellets were suitable substrates for earthworm biomass formation (Hanc et al., 2021). The decomposition of spent mushroom substrate-based bedding material supplemented with cassava pulp and fruit peel waste improved the growth of earthworms and the chemical properties of fertilizers (Ruangjanda et al., 2022). Vermicompost with bedding derived from spent mushroom waste, coconut husk, and sugarcane trash provides the best direct and residual effect on the soil nutrient and crop yield (Nurhidayati et al., 2018). Effective vermicompost was produced from other organic residues that served as bedding material, such as potato plant biomass (Das and Deka, 2021) and dairy shed solids with horticultural factory wastes (Xue et al., 2022). Thailand, a country grappling with a constant influx of organic waste from agriculture, animal husbandry, and industry, has been actively exploring vermicomposting techniques as a sustainable waste management strategy. A series of studies conducted by Klangkongsub and Sohsalam (2013); Taeporamaysamai and Ratanatamskul (2016); Boonna et al. (2020); Klomklang et al. (2021), and Ruangjanda et al. (2022) have shed light on the significance of vermicomposting in the context of Thailand's organic waste recycling efforts. Notably, the abundance of coffee grounds, spent mushroom waste, and white popinac leaves present an opportunity to harness these organic materials for vermicompost production.

Furthermore, Thailand's thriving cultivation of chili and cabbage, with 2021 production figures standing at around 19 and 256 kilotons respectively, necessitates a sustainable approach to seedling production. Currently, many imported seedling materials rely on peat moss, incurring significant costs. Vermicompost, characterized by its peat-like texture, high porosity, and water retention capacity, offers a compelling alternative. Existing research, as demonstrated by Vithirak and Iwai (2019); Flores-Solórzano et al. (2022), and Kauser and Khwairakpam (2022), has illustrated the positive impact of vermicompost on seed germination and seedling growth.

In light of these considerations, this study centers on evaluating the effects of vermicomposts derived from various locally sourced organic wastes, including cow dung, spent mushroom waste, coffee grounds, and white popinac leaves, either individually or in diverse combinations. The analysis encompassed its macronutrient content and its influence on the growth of cabbage and chili seedlings representing leafy and fruit-bearing crops, respectively. The primary goal was to determine the suitability of vermicompost as a nursery material.

2. Material and methods

Source of organic material, earthworm, and plant seeds

Organic wastes served as bedding material, and worm feed were cow dung, spent mushroom waste, coffee grounds, and white popinac leaves. Cow dung was obtained from a livestock farm near the research site at the Faculty of Agricultural Technology of Lampang Rajabhat University in Lampang Province, Thailand. The spent mushroom waste and coffee grounds were kindly provided by Wiang Hong farm and coffee shops around the research location, respectively. White popinac leaves were collected from trees that were widely distributed throughout the university. They were air-dried before being used.

The earthworm species *Eudrilus eugeniae*, is preferred for commercial production in tropical areas due to their rapid growth and tolerance to high temperatures. They were purchased from Kru Tai earthworm farm, Lampang. Seeds of cabbage (*Brassica oleracea*) and chili (*Capsicum annuum*), and commercial nursery material (peat moss and vermiculite) were purchased from an agricultural supplier store in Lampang.

Vermicompost preparation

The vermicompost was produced from a mixture of different bedding in a total of 10 methods (Table 1). These methods included three individual main materials (cow dung, spent mushroom waste, coffee grounds), mixtures of two main materials, a mixture of all three main materials, and mixtures of two main materials with an additive (white popinac leaves). Cow dung was soaked in the water for three days or until it is cooled down before use. Each mixture of bedding was put in a plastic bow (42 cm in diameter, 18 cm in depth) with a total volume of approximately 0.02 cubic meters. Three hundred grams of earthworms were placed on each bedding, and the bedding was kept moist by daily spraying with water. The bedding container was placed in a shady area for 60 days, with ambient temperatures ranging

Table 1. Combination of organic material in vermicomposting process.

Treatments	Bedding materials	Symbol
1	100% cow dung	CD
2	100% spent mushroom waste	SM
3	100% coffee grounds	CG
4	1:1 (v/v) of cow dung and spent mushroom waste	CD:SM
5	1:1 (v/v) of spent mushroom waste and coffee grounds	SM:CG
6	1:1 (v/v) of cow dung and coffee grounds	CD:CG
7	1:1:1 (v/v) of cow dung, spent mushroom waste, and coffee grounds	CD:SM:CG
8	1:1:1 (v/v) of cow dung, spent mushroom waste and white popinac leaves	CD:SM:WPL
9	1:1:1 (v/v) of spent mushroom waste, coffee grounds and white popinac leaves	SM:CG:WPL
10	1:1:1 (v/v) of cow dung, coffee grounds, and white popinac leaves	CD:CG:WPL
11	commercial nursery mix, 1:1 (v/v) of peat moss and vermiculite	CNM

from 17 to 30 degrees Celsius. After two months, each vermicompost was collected and analyzed for the amount of nitrogen by the Kjedahl method (Csuros, 1997), phosphorus by the Bray II method (Bray and Kurtz, 1945) and potassium by atomic emission spectrophotometer (AOAC, 2000) at Central Laboratory, Faculty of Agriculture, Chiang Mai University, Thailand. The N P K of commercial nursery material, a mixture of peat moss and vermiculite, was also analyzed.

Seedling growth experiment

Each vermicompost produced from different bedding was mixed thoroughly with fine coconut coir at the ratio of 1:1 (v/v) and then used as nursery planting material. They were put in 104 cell seedling trays before the seeds of cabbage and chili were planted in each hole. The experiment was performed in three replicates, each with a total of 20 seeds. The commercial nursery mix (CNM) was used as a control. The seedling trays were placed in the green house and watered twice a day. Four weeks after seed germination, seedlings from the tray were harvested. Plant height (cm), leaf width (cm), leaf length (cm), and number of leaves per plant were measured. The experiment was arranged in a completely randomized design. Data were analyzed by statistical analysis software, and ANOVA was performed for testing. Duncan's new multiple range test (DMRT) at a 95% confidence level was used for the mean comparison of treatments at $P<0.05$.

3. Results and discussion

Chemical characteristics of vermicompost

Vermicompost from different organic waste used as earthworm feed had different amounts of macronutrients, N P K (Table 2). The highest N nutrient was found in vermicompost 10 and 6, where cow dung and coffee grounds were used as bedding substrates. In all treatments, the N content was higher than that of the commercial nursery mix (control). The concentrations of P and K were found to be highest in vermicompost 1 (100% cow dung). In treatments without cow dung, the P and K values were lower than those in the commercial nursery mix. Cattle manure was often used as a main substrate for earthworm growth and repro-

Table 2. Macronutrient concentration of vermicompost produced from different bedding mixes.

Treatments	N (%)	P (g/kg)	K (g/kg)
1 (CD)	2.51 ± 0.01^{d}	3.06 ± 0.09^{a}	7.08 ± 0.39^{a}
2 (SM)	1.33 ± 0.01^{h}	$0.33\pm0.00f^{g}$	2.40 ± 0.03^{g}
3 (CG)	2.91 ± 0.01^{c}	0.44 ± 0.03^{f}	3.04 ± 0.00^{f}
4 (CD:SM)	1.97 ± 0.01^{g}	2.63 ± 0.18^{b}	5.22 ± 0.11^{c}
5 (SM:CG)	2.42 ± 0.00^{f}	0.17 ± 0.00^{gh}	2.43 ± 0.02^{g}
6 (CD:CG)	3.34 ± 0.00^{b}	2.44 ± 0.09^{b}	5.76 ± 0.04^{b}
7 (CD:SM:CG)	2.46 ± 0.02^{e}	1.31 ± 0.09^{d}	3.66 ± 0.02^{e}
8 (CD:SM:WPL)	1.95 ± 0.01^{g}	1.62 ± 0.18^{c}	4.75 ± 0.08^{d}
9 (SM:CG:WPL)	2.51 ± 0.02^{d}	0.12 ± 0.00^{h}	3.11 ± 0.04^{f}
10 (CD:CG:WPL)	3.50 ± 0.01^{a}	1.56 ± 0.09^{c}	5.59 ± 0.02^{bc}
11 (CNM)	0.53 ± 0.01^{i}	1.06 ± 0.09^{e}	3.72 ± 0.14^{e}
F-test			
P-value	0.0000	0.0000	0.0000
C.V. (%)	0.65	6.95	4.20

Note: Values are mean (n=3) ± SE. Value with different lowercase letters in the same column indicate significant differences at $P<0.05$ (DMRT) duction because of its richness in nutrients (Gupta et al., 2014; Nurhidayati et al., 2016; Nurhidayati et al., 2018; Blouin et al., 2019; Singh et al., 2020b; Alipour et al., 2023; Syarifinnur et al., 2022). Vermicompost 2 (100% spent mushroom waste) had the lowest N and K concentration. Moreover, the N P K values were low in most vermicomposts using bedding of spent mushroom waste as a substrate component. Nurhidayati et al. (2018) reported that bedding obtained from the spent mushroom waste provided a low nutrient release because of its high lignin content. Lower P and K nutrients were also found in coffee grounds derived vermicompost without cow dung used (vermicompost 3, 5, and 9). The macronutrient content of vermicompost was higher when cow dung was added to the bedding material mixture. Agricultural waste should be mixed with animal manure to produce efficient vermicomposting (Singh et al., 2020b). In this study, the nutrient concentration of vermicompost produced by *E. eugenia* species appears to be lower than that Ruangjanda et al. (2022) had previously reported. A significant difference was observed between vermicomposts obtained from different organic materials with different macronutrient content. The nutrient quality of vermicompost varies and depends on the material used as worm feed (Ansari et al., 2020). The average nutrient contents in vermicompost have been reported with variations. For example, Pierre-Louis et al. (2021) reported N content in the range of 1.3-1.84%, P content between 0.92-1.3%, and K content between 0.21-1.2%. On the other hand, Rehman et al. (2023) found N content between 1.5-2%, P content between 1.8-2.2%, and K content between 1-1.5%. The variability in cast fertility may depend on the interaction between earthworm species traits and specific soil properties (Elissen et al., 2023). There was no significant difference in pH between treatments, which consistently measured between 6.8 and 7.2.

Effect of vermicompost on seedling growth

-Cabbage seedling growth

Four weeks after the seed germination, plant height, leaf width, leaf length, and leaf number per plant showed a highly significant difference between treatments at $P<0.05$ (Table 3). The plant height of cabbage seedlings was the highest when grown in vermicompost 8. It was not significantly different with the commercial nursery mix (11) and vermicompost 4 treatment. The highest leaf width, leaf length, and leaf number per plant were observed in treatment with vermicomposts 8, 4, 10, 1, 6, and 11. Applying vermicompost produced from spent mushroom waste and coffee grounds or both without cow dung (vermicomposts 2, 3, 5, and 9) caused a negative effect on the growth of cabbage seedlings (Fig. 1). This might be related to the low P and K nutrient content. The result demonstrated that vermicomposts 8 and 4 were as highly effective as a nursery material for cabbage seedling production as a commercial nursery mix. Their beddings were prepared by using cow dung and spent mushroom waste. Nurhidayati et al. (2016) reported that plants growing with vermicompost produced by using mushroom media waste as a main substrate in a mixture with cow manure could increase the yield and quality of cabbage.

-Chili seedling growth

Four weeks after the seed germination, plant height, leaf width, leaf length, and leaf number of the plant showed a highly significant difference between treatments at $P<0.05$ (Table 4). The plant height of chili seedlings in treatments with vermicomposts 1, 4, 6, 8, and 10 was higher than that of vermicomposts 2, 3, 5, 7, and 9. The highest plant height was found in the control set (11). However, the leaf width of seedlings grown in vermicomposts 1, 4, 6, 8, and 10 was not significantly different from the control. Different bedding of vermicompost affected leaf length and leaf number of chilies. Chili seedlings in the control treatment had the highest leaf length and leaf number per plant but were not significantly different from the vermicomposts 1, 4, 8, and 10. The shortest leaf length and the smallest amount of leaf number of chili seedlings were observed in treatments with vermicomposts 2, 3, 5, 7, and 9 (Fig. 2), consistent with the cabbage experiment. All vermicompost produced in the present study were not appropriate to use as a nursery material for chili seedling production compared with commercial nursery mix. Rekha et al. (2018) revealed that the growth of chili (*C. annuum*) was increased in cow dung-derived vermicompost, inconsistent with this study.
Vermicompost derived from different bedding showed significant differences in macronutrient content and growth of cabbage and chili seedlings. Although the concentration of macronutrients in commercial nursery material was lower than that of vermicompost, seedling growth was not different. Macronutrients in vermicompost are sufficient for the growth of both cabbage and chili seedlings. However, chili seedlings showed less growth, possibly due to other factors affecting plant growth. Vithirak and Iwai (2019)

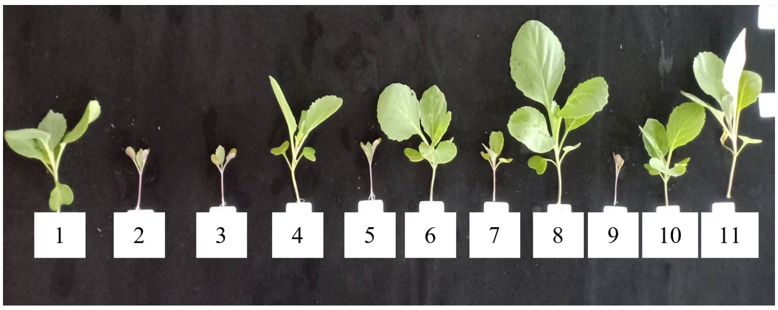

Figure 1. Cabbage seedlings grown in different vermicompost after 4 weeks of seed germination.

Table 3. Growth of cabbage seedlings after germination for 4 weeks in different vermicompost substrates.

Treatments	Height (cm)	Leaf width (cm)	Leaf length (cm)	Leaf no. per plant
1 (CD)	5.66±0.17^{bc}	2.96±0.08^{a}	3.53±0.10^{a}	3.60±0.12^{a}
2 (SM)	2.60±0.09^{d}	1.03±0.05^{b}	0.73±0.05^{b}	0.35±0.00^{e}
3 (CG)	2.30±0.15^{d}	1.13±0.01^{b}	1.16±0.04^{b}	2.26±0.18^{b}
4 (CD:SM)	6.00±0.52^{abc}	3.13±0.31^{a}	3.76±0.31^{a}	3.66±0.07^{a}
5 (SM:CG)	2.40±0.02^{d}	1.10±0.02^{b}	0.93±0.04^{b}	0.93±0.37^{cd}
6 (CD:CG)	5.56±0.56^{bc}	2.80±0.19^{a}	3.40±0.29^{a}	3.46±0.24^{a}
7 (CD:SM:CG)	2.53±0.06^{d}	1.20±0.09^{b}	1.36±0.08^{b}	1.20±0.12^{c}
8 (CD:SM:WPL)	7.33±0.47^{a}	3.26±0.32^{a}	4.06±0.31^{a}	4.00±0.00^{a}
9 (SM:CG:WPL)	2.46±0.09^{d}	1.10±0.01^{b}	0.86±0.03^{b}	0.33±0.07^{e}
10 (CD:CG:WPL)	5.40±0.12^{c}	3.00±0.06^{a}	3.63±0.08^{a}	3.60±0.23^{a}
11 (CNM)	7.06±0.45^{ab}	3.03±0.26^{a}	4.00±0.21^{a}	3.66±0.07^{a}
F-test				
P-value	0.0000	0.0000	0.0000	0.0000
C.V. (%)	12.08	13.67	12.37	12.16

Note: Values are mean (n=3) ± SE. Values with different lowercase letters in the same column indicate significant differences at P<0.05 (DMRT)

Table 4. Growth of chili seedlings after germination for 4 weeks in different vermicompost substrates.

Treatments	Height (cm)	Leaf width (cm)	Leaf length (cm)	Leaf no. per plant
1 (CD)	8.22±0.43^{b}	1.86±0.07^{a}	3.70±0.15^{ab}	5.33±0.24^{a}
2 (SM)	3.40±0.06^{c}	0.46±0.02^{b}	1.43±0.09^{c}	2.20±0.12^{d}
3 (CG)	3.36±0.04^{c}	0.50±0.01^{b}	1.36±0.04^{c}	2.73±0.18^{d}
4 (CD:SM)	8.63±0.69^{b}	2.03±0.16^{a}	3.93±0.22^{ab}	4.26±0.07^{bc}
5 (SM:CG)	3.33±0.09^{c}	0.53±0.02^{b}	1.33±0.05^{c}	2.33±0.07^{d}
6 (CD:CG)	8.23±0.08^{b}	1.86±0.06^{a}	3.53±0.14^{b}	4.66±0.24^{abc}
7 (CD:SM:CG)	3.63±0.07^{c}	0.63±0.02^{b}	1.40±0.02^{c}	2.60±0.20^{d}
8 (CD:SM:WPL)	9.56±0.09^{b}	2.00±0.02^{a}	3.96±0.06^{ab}	5.00±0.12^{ab}
9 (SM:CG:WPL)	3.53±0.10^{c}	0.50±0.01^{b}	1.33±0.05^{c}	2.26±0.07^{d}
10 (CD:CG:WPL)	8.10±0.51^{b}	1.86±0.06^{a}	3.63±0.13^{b}	4.60±0.20^{abc}
11 (CNM)	11.60±0.60^{a}	2.13±0.02^{a}	4.30±0.23^{a}	5.33±0.13^{a}
F-test				
P-value	0.0000	0.0000	0.0000	0.0000
C.V. (%)	9.30	9.12	8.04	7.65

Note: Values are mean (n=3)±SE. Values with different lowercase letters in the same column indicate significant differences at P<0.05 (DMRT)

Figure 2. Chili seedlings grown in different vermicompost after 4 weeks of seed germination.

revealed that a high concentration of vermicompost could decrease lettuce seed germination. The treatment with appropriate amounts of vermicompost positively affects the growth and flowering of marigold seedlings (Gupta et al., 2014). Ma et al. (2022) reported that the optimum proportion of vermicompost for plant growth in a growing medium was 40–60%. Thus, the appropriate concentration or quantities of vermicompost to be applied in growing media for each plant species should be investigated. In addition, another factor that can increase crop yield might be related to the improvement of soil physical properties affected by vermicompost application.

Plant growth stimulation may depend mainly on the biological characteristics of vermicompost, the plant species used, and the cultivation conditions (Singh et al., 2020a). Some waste materials may be unsuitable when used alone as a bedding substrate in the vermicomposting process. Vermicompost with bedding derived from spent mushroom waste or coffee grounds or its combination negatively affects the growth of cabbage and chili seedlings. Yamane et al. (2014) revealed that the soil incorporated with coffee grounds showed negative responses to the growth of green manure crops due to the coffee pulp of husk containing some caffeine and tannins, making it toxic in nature. However, coffee grounds and their mixtures with straw pellets could be used to produce vermicompost, and caffeine was reduced by the earthworm process (Hanc et al., 2021). The effect of vermicompost using bedding of spent mushroom waste on mustard yield reported by Nurhidayati et al. (2018) was inconsistent with this study. Application of spent mushroom waste-vermicompost in soil provided a high mustard yield on the first cropping. Ruangjanda et al. (2022) investigated the effect of other organic wastes on the vermicomposting process of spent mushroom waste. The results demonstrated that the treatments supplemented with cassava pulp and fruit peel waste improved earthworm growth.

4. Conclusion

The vermicompost derived from cow dung, whether used alone or in combination with other organic waste, had substantial macronutrient concentration. Still, they had different effects on the growth of cabbage and chili seedlings. Spent mushroom waste and coffee grounds were useful organic materials when used in a mixture with cow dung as a bedding substrate in the vermicomposting process. Two types of vermicompost, obtained from a blend of cow dung and spent mushroom waste, along with the addition of white popinac leaves, were effective nursery material for cabbage seedling cultivation, but none of the vermicompost was appropriate for chili seedlings. This research indicated that vermicomposting, a low-cost and effective technique, was a solution to reduce the amount of organic waste going to landfills and generate a nutrient-rich natural fertilizer from unused waste for efficient plant production. Combination of local organic waste, applying concentration, suitability for plant species, etc., should be further studied and practiced.

Acknowledgment
The authors are grateful to Lampang Rajabhat University for all the facilities in this work and to Wiang Hong farm and Café Amazon for organic waste materials support. The authors are also thankful for valuable suggestions by Assoc. Prof. Dr. Chitnarong Sirisathitkul, Asst. Prof. Yaowarat Sirisathitkul and Prof. Dr. Bernard Dell.

Author contribution
Haruthai Thaisuchat: literature collection, interpretation of results, writing-review and editing. Purepan Panikanan: data curation. Jumnian Meesumlee: conceptualization, methodology, analysis and interpretation of results, writing-original draft. All authors have read and agreed to the published version of the manuscript.

Conflict of interest statement
The authors declare that they are no conflict of interest associated with this study.

References

Alipour SM, Fataei E, Nasehi F, Imani AA (2023) Vermicompost quality and earthworm reproduction in different organic waste substrates. *Int J Recycl Org Waste Agricul* 12 (3): 325–339. https://doi.org/10.30486/ijrowa.2022.1944906.1371

Ansari AA, Ori L, Ramnarain YI (2020) An effective organic waste recycling through vermicompost technology for soil health restoration. *In: Meena RS (ed) Soil Health Restoration and Management,* 83–112. https://doi.org/10.1007/978-981-13-8570-4_3

AOAC (2000) Official Method of Analysis of AOAC International: The Association of Official Analytical Chemists, 17th edn. *Aoac Intl, Washington DC*

Blouin M, Barrere J, Meyer N, Lartigue S, Barot S, Mathieu J (2019) Vermicompost significantly affects plant growth. A meta-analysis. *Agron Sustain Dev* 39:34. https://doi.org/10.1007/s13593-019-0579-x

Boonna P, Kungskulniti N, Tangkoonboribun R, Charoenca N (2020) Vermicomposting different organic wastes to determine suitability for use in organic farming. *Int J GEOMATE* 18 (68): 29–34. https://doi.org/10.21660/2020.68.5591

Bray RH, Kurtz LT (1945) Determination of total organic and available forms of phosphorus in soils. *Soil Science* 59:39–45. https://doi.org/10.1097/00010694-194501000-00006

Csuros M (1997) Environmental sampling and analysis: lab manual. *CRC Press, New York,* https://doi.org/10.1201/9780203756881

Das D, Deka H (2021) Vermicomposting of harvested waste biomass of potato crop employing *Eisenia fetida*: Changes in nutrient profile and assessment of the maturity of the end products. *Environ Sci Pollut Res* 28 (27): 35717–35727. https://doi.org/10.1007/s11356-021-13214-z

Das N, Islam MS, Kashem MA, Osman KT (2022) Influence of one-time application of vermicompost and NPK fertilizers on the growths and mineral nutrients of Indian spinach (Basella alba L.). *J Soil Sci Plant Nutr* 22 (2): 2307–2321. https://doi.org/10.1007/s42729-022-00810-2

Elissen H, Weide R van der, Gollenbeek L (2023) Effects of vermicompost on plant and soil characteristics – A literature overview. *Wageningen Research,* https://doi.org/10.18174/587210

Esteves GDF, Souza KRD de, Bressanin LA, Andrade PCC, Júnior V Veroneze, Reis PE dos, Silva AB da, et al. (2020) Vermicompost improves maize, millet and sorghum growth in iron mine tailings. *J Environ Manage* 264:110468. https://doi.org/10.1016/j.jenvman.2020.110468

Flores-Solórzano SB, Huerta-Lwanga E, Cuevas-González1 R, Guillén-Navarro K (2022) Optimal conditions to produce extracts of compost and vermicompost from oil palm and coffee pulp wastes. *J Mater Cycles Waste Manag* 24:801–810. https://doi.org/10.1007/s10163-022-01365-1

Gupta R, Yadav A, Garg VK (2014) Influence of vermicompost application in potting media on growth and flowering of marigold crop. *Int J Recycl Org Waste Agricul* 3 (1): 1–7. https://doi.org/10.1007/s40093-014-0047-1

Hanc A, Hrebeckova T, Grasserova A, Cajthaml T (2021) Conversion of spent coffee grounds into vermicompost. *Bioresour Technol* 341:125925. https://doi.org/10.1016/j.biortech.2021.125925

Joshi R, Singh J, Vig AP (2015) Vermicompost as an effective organic fertilizer and biocontrol agent: effect on growth, yield and quality of plants. *Rev Environ Sci Biotechnol* 14:137–159. https://doi.org/10.1007/s11157-014-9347-1

Kauser H, Khwairakpam M (2022) Organic waste management by two-stage composting process to decrease the time required for vermicomposting. *Environ Technol Innov* 25:102193. https://doi.org/10.1016/j.eti.2021.102193

Klangkongsub S, Sohsalam P (2013) Vermicompost production by using tomato residue and yard waste. *J Med Biol Eng* 2 (4): 270–273. https://doi.org/10.12720/jomb.2.4.270-273

Klomklang U, Kulsirilak N, Intaravicha N, Supakata N (2021) Vermicompost from Chula zero waste cup and rain tree (*Samanea saman*) leaves. *Eng J* 25 (4): 1–10. https://doi.org/10.4186/ej.2021.25.4.1

Liégui GS, Cognet S, Djumyom GVW, Atabong PA, Noutadié JPF, Chamedjeu RR, Temegne CN, Kengne IMN (2021) An effective organic waste recycling through vermicomposting technology for sustainable agriculture in tropics. *Int J Recycl Org Waste Agricul* 10 (3): 203–214. https://doi.org/10.30486/ijrowa.2021.1894997.1080

Ma H, Zhao S, Hou J, Feyissa T, Duan Z, Pan Z, Zhang K, Zhang W (2022) Vermicompost improves physicochemical properties of growing medium and promotes plant growth: A meta-analysis. *J Soil Sci Plant Nutr* 22:3745–3755. https://doi.org/10.1007/s42729-022-00924-7

Nurhidayati N, Ali U, Murwani I (2016) Yield and quality of cabbage (*Brassica oleracea* L.var. Capitata) under organic growing media using vermicompost and earthworm *Pontoscolex corethrurus* inoculation. *Agric Sci Procedia* 11:5–13. https://doi.org/10.1016/j.aaspro.2016.12.002

Nurhidayati N, Machfudz M, Murwani I (2018) Direct and residual effect of various vermicompost on soil nutrient and nutrient uptake dynamics and productivity of four mustard Pak-Coi (*Brassica rapa* L.) sequences in organic farming system. *Int J Recycl Org Waste Agricul* 7 (2): 173–181. https://doi.org/10.1007/s40093-018-0203-0

Pierre-Louis RC, Kader MdA, Desai NM, John EH (2021) Potentiality of vermicomposting in the South Pacific Island countries: A review. *Agriculture* 11:876. https://doi.org/10.3390/agriculture11090876

Raza ST, Zhu B, Yao Z, Wu J, Chen Z, Ali Z, Tang JL (2023) Impacts of vermicompost application on crop yield, ammonia volatilization and greenhouse gases emission on upland in Southwest China. *Sci Total Environ* 860:160479. https://doi.org/10.1016/j.scitotenv.2022.160479

Rehman SU, Castro F De, Aprile A, Benedettti M, Fanizzi FP (2023) Vermicompost: Enhancing plant growth and combating abiotic and biotic stress. *Agronomy* 13 (4): 1134. https://doi.org/10.3390/agronomy13041134

Rekha GS, Kaleena PK, Elumalai D, Srikumaran MP, Maheswari VN (2018) Effects of vermicompost and plant growth enhancers on the exo-morphological features of *Capsicum annum* (Linn.) Hepper. *Int J Recycl Org Waste Agricul* 7 (1): 83–88. https://doi.org/10.1007/s40093-017-0191-5

Ruangjanda S, Iwai CB, Greff B, Chang SW, Ravindran B (2022) Valorization of spent mushroom substrate in combination with agro-residues to improve the nutrient and phytohormone contents of vermicompost. *Environ Res* 214:113771. https://doi.org/10.1016/j.envres.2022.113771

Schröder C, Häfner F, Larsen OC, Krause A (2021) Urban organic waste for urban farming: Growing lettuce using vermicompost and thermophilic compost. *Agronomy* 11 (6): 1175. https://doi.org/10.3390/agronomy11061175

Sharafabad ZH, Abdipour M, Hosseinifarahi M, Kelidari A, Rashidi L (2022) Integrated humic acid and vermicomposting changes essential oil quantity, and quality in field-grown *Lavandula angustifolia* L. inter-cropped with *Brassica nigra* L. *Ind Crops Prod* 178:114635. https://doi.org/10.1016/j.indcrop.2022.114635

Shen Z, Yu Z, Xu L, Zhao Y, Yi S, Shen C, Wang Y, et al. (2022) Effects of vermicompost application on growth and heavy metal uptake of barley grown in mudflat salt-affected soils. *Agronomy* 12 (5): 1007. https://doi.org/10.3390/agronomy12051007

Singh A, Kumar V, Verma S, Majumdar M, Sarkar S (2020a) Significance of vermicompost on crop and soil productivity: A review. *Int J Chem Stud* 8 (5): 1529–1534. https://doi.org/10.22271/chemi.2020.v8.i5u.10517

Singh S, Singh J, Kandoria A, Quadar J, Bhat SA, Chowdhary AB, Vig AP (2020b) Bioconversion of different organic waste into fortified vermicompost with the help of earthworm: A comprehensive review. *Int J Recycl Org Waste Agricul* 9 (4): 423–439. https://doi.org/10.30486/ijrowa.2020.1893367.1037

Swati A, Hait S (2018) A comprehensive review of the fate of pathogens during vermicomposting of organic wastes. *J Environ Qual* 47 (1): 16–29. https://doi.org/10.2134/jeq2017.07.0265

Syarifinnur S, Nuraini Y, Prasetya B, Handayanto E (2022) Comparing compost and vermicompost produced from market organic waste. *Int J Recycl Org Waste Agricul* 12 (3): 279–289. https://doi.org/110.30486/ijrowa.2022.1944251.1368

Taeporamaysamai O, Ratanatamskul C (2016) Co-composting of various organic substrates from municipal solid waste using an on-site prototype vermicomposting reactor. *Int Biodeter Biodegr* 113:357–366. https://doi.org/10.1016/j.ibiod.2016.05.009

Vithirak H, Iwai CB (2019) Effect of vermicompost tea on seed germination of Green Romaine (*Lactuca sativa* L. var. Jericho) and Green Batavia (*Lactuca sativa* L.var Concept) lettuce. *Khon Kaen Agr* 47 (2) https://doi.org/10.14456/kaj.2019.27

Wang F, Wang X, Song N (2021) Biochar and vermicompost improve the soil properties and the yield and quality of cucumber (*Cucumis sativus* L.) grown in plastic shed soil continuously cropped for different years. *Agric Ecosyst Environ* 315:107425. https://doi.org/10.1016/j.agee.2021.107425

Xue J, Bakker MR, Milin S, Graham D (2022) Enhancement in soil fertility, early plant growth and nutrition and mycorrhizal colonization by vermicompost application varies with native and exotic tree species. *J Soils Sediments* 22 (6): 1662–1676. https://doi.org/10.1007/s11368-022-03180-5

Yamane K, Kono M, Fukunaga T, Iwai K, Sekine R, Watanabe Y, Iijima M (2014) Field evaluation of coffee ground application for crop growth enhancement, weed control, and soil improvement. *Plant Prod Sci* 17 (1): 93–102. https://doi.org/10.1626/pps.17.93