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Evaluating the Potential of Local Agricultural Residues for Sustainable Fertilizer Production: Enhancing Soil Health and Crop Productivity in Narathiwat, Thailand, Contributing to Sustainable Development Goals

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ABSTRACT

Background: This study evaluates the potential of local agricultural residues namely longkong peel, cajeput bark and oil palm bunches-as sustainable alternatives for fertilizer production in Narathiwat Province, Thailand. The use of compost made from these residues can offer a cost-effective and environmentally friendly solution to improve soil fertility and reduce dependency on chemical fertilizers.

Methods: The raw residues and their corresponding composts were chemically analyzed for their nutrient content. Fertilizer equivalence was calculated to estimate their potential contribution to soil nutrient supply. A plant growth experiment was conducted involving treatments comprising of longkong peel, cajeput bark and oil palm bunch composts, as well as a control group and standard fertilization to assess the influence of these composts on plant height and fresh weight.

Result: The chemical analysis showed that longkong peel compost had the highest nutrient content, with (2.59% N; 1.41% P_2O_5 and 2.96% K_2O). Cajeput bark compost having a higher carbon-to-nitrogen (C/N) ratio, resulted in slower decomposition and nutrient release. Oil palm bunch compost displayed moderate nutrient levels. Fertilizer equivalence analysis indicated that longkong peel compost provided the highest nutrient equivalence, with an estimated annual contribution of 610 tons of nitrogen, 332 tons of phosphorus and 698 tons of potassium. Plant growth experiments with maize showed that longkong peel and oil palm bunch composts (145.75 cm in height and 80.75 g in fresh weight) being highest with oil palm bunch. significantly improved plant height and fresh weight. Cajeput bark compost also enhanced plant growth, but to a lesser degree.

Key words: Agricultural residues, Compost, Fertilizer equivalence, Narathiwat, Plant growth, Soil fertility, Sustainable fertilizer.

INTRODUCTION

Agriculture is a vital sector in Thailand, accounting for more than 50% of the country's land use. However, agricultural productivity is in declining phase, primarily due to soil degradation, over-reliance on chemical fertilizers and unsustainable farming practices. In Narathiwat Province, a region predominantly dependent on agriculture, sandy soils covering approximately 22,135 rai, pose significant challenges to crop production. These soils are characterized by low organic matter content, poor water retention and poor nutrient availability, which significantly hinder agricultural productivity and raise concerns about long-term soil health.

To address these challenges and improve soil fertility, farmers in Narathiwat have traditionally relied on chemical fertilizers. While these fertilizers offer immediate results, their excessive use has led to soil degradation, reduced microbial diversity and environmental pollution. The harmful effects of chemical fertilizers on soil health and human well-being have prompted a shift toward more sustainable practices. The use of organic fertilizers has been shown to improve soil properties, enhance microbial activity and support sustainable crop production (Begum *et al.,* 2025; Ghedabna *et al.,* 2023). Moreover, integrating organic amendments with balanced NPK nutrients can significantly enhance the effectiveness of biological agents such as *Biofresh*, leading to improved disease resistance, increased crop yield and better soil quality, particularly in marginal lands (Wijayanto *et al.,* 2022). The overuse of synthetic inputs in farming systems has highlighted the urgent need for alternative practices that are both sustainable and environmentally friendly. Among these alternatives, organic amendments such as compost have gained attention for their ability to enhance soil health, improve nutrient availability and restore

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soil fertility, all while mitigating the environmental impacts associated with synthetic fertilizers.

One promising solution to this problem lies in utilizing the large quantities of agricultural residues produced in Narathiwat. Key crops in the region are longkong (Lansium domesticum), oil palm (*Elaeis guineensis*) and cajeput (Melaleuca cajuputi) and generate substantial amounts of organic waste that could be converted into valuable compost. Longkong, cultivated on 43,396 rai and recognized as a Geographical Indication (GI) product under the name "Longkong Tanyongmas," produces large quantities of fruit peels that are often underutilized. Oil palm plantations, which cover approximately 65,659 rai in the region, generate empty bunches, a residue with considerable potential for composting. Similarly, cajeput trees, native to the Phru Toh Daeng peat swamp forest, produce bark residues rich in organic matter that could be converted into compost for soil enhancement. These agricultural residues represent a substantial untapped resource and their conversion into compost could provide a sustainable means of improving soil fertility while recycling agricultural waste.

This study aims to evaluate the effects of compost made from longkong peel, cajeput bark and empty oil palm bunches, these residues were analysed for nitrogen, phosphorus, potassium and other essential soil nutrients, to determine their suitability as organic fertilizers and estimate the fertilizer equivalence of each compost, calculating their potential contribution to nutrient supply in agricultural systems and compare these values with conventional chemical fertilizers as well as assess whether current composting practices and the nutrient levels of the compost can meet the nutritional needs of crops grown in the sandy soils of Narathiwat, particularly for long-term sustainable farming practices.

Through these objectives, the study assesses the viability of local agricultural residues as sustainable sources of organic fertilizers in Narathiwat. Moreover, the results will inform local agricultural policies, support farmers in transitioning to more sustainable practices and contribute to broader environmental and development goals. In the context of global sustainability, this research aligns with the United Nations Sustainable Development Goals (SDGs). Specifically, it contributes to SDG 2 (Zero Hunger) by improving soil fertility and crop yields, SDG 12 (Responsible Consumption and Production) by promoting the recycling of agricultural waste into valuable compost and SDG 13 (Climate Action) by reducing reliance on synthetic fertilizers and mitigating their environmental impacts.

MATERIALS AND METHODS

The plant residues selected for this study were longkong peel (from longkong, Lansium domesticum), cajeput bark (from cajeput, Melaleuca cajuputi) and empty oil palm bunches (from Elaeis guineensis). These residues were chosen based on their availability in the region and their potential for compost production. The residues were sourced from local farms and processing facilities with proper consent from landowners. To evaluate the composting potential of these residues, compost was prepared for each plant type using a mix of 78% plant residue, 20% chicken manure and 2% urea fertilizer, with the addition of 150 g of microbial activator (PD1; Land Development Department, Thailand). The materials were layered in composting bins, each layer approximately 25 cm thick. The composting process was aerobic, with materials turned manually every two weeks to ensure proper decomposition. The compost was monitored for maturity, indicated by dark coloration, fine texture, earthy odor and a reduction in moisture content. This composting method was designed to reflect real local practices for organic fertilizer production of compost on plant growth, a pot experiment was conducted with the following objectives evaluate how different compost types influence plant growth (height and fresh weight) and compare the effectiveness of the three compost types in improving plant development in sandy soils. The experimental design used was a completely randomized design (CRD) with four treatments, replicated five times: TR1: Control (no compost), TR2: Longkong peel compost, TR3: Cajeput bark compost and TR4: Empty oil palm bunch compost. Each compost type was mixed with sandy soil at a 1:1 volume-to-volume ratio, a commonly used ratio for compost application in sandy soils. Corn (*Zea mays* L.) was chosen as the test crop due to its fast growth and significance in local agriculture. Three seeds were sown per pot and after one week, the weakest seedlings were removed, leaving one healthy seedling per pot. Plants were irrigated regularly to maintain field capacity and ensure consistent moisture. Plant growth was monitored by measuring plant height (cm) and fresh weight (g). These parameters were measured 45 days after sowing, providing an indicator of the plants' response to compost amendments. Height was measured from the soil surface to the tip of the tallest leaf, while fresh weight was recorded after harvest, serving as a metric for overall plant biomass and health. To assess the quality and nutrient availability of the composts, chemical analyses were performed on each compost type. The following properties were measured: pH: Measured with a pH meter (S220, Mettler Toledo), Electrical conductivity (EC): Measured with an EC meter (S30-K, Mettler Toledo), Organic matter (OM): Determined using the Walkley-Black method, Organic carbon (OC): Calculated as OM $\times$ 1.72, Total nitrogen (N): Determined by the Kjeldahl method, Total phosphorus (P): Measured by colorimetry (UV-160A, Shimadzu Corporation), Total potassium (K): Measured by atomic absorption spectroscopy (AA-6300, Shimadzu Corporation) and Carbon-to-nitrogen ratio (C/N): Calculated from OC and N values. These analyses provided the data needed to assess the nutrient content and quality of the composts, facilitating comparisons between the residues and their suitability for composting. The fertilizer Equivalence Estimation, the study aimed to estimate how

well each compost could replace conventional synthetic fertilizers, such as urea (46% N), single superphosphate (SP36, 36% P_2O_5) and potassium chloride (KCl, 60% K_2O). The nutrient content (N, P, K) of each compost was converted into the equivalent amounts of these chemical fertilizers. This comparison helped quantify the fertilizer equivalence of the composts and assess their potential for sustainable soil fertility management in the region. The estimation of compost production and application potential, this study estimates the potential for large-scale compost production, data on local crop production and residue availability were obtained from the Narathiwat Provincial Development Plan 2024. The availability of longkong peel, cajeput bark and oil palm bunches was calculated based on current agricultural practices. Potential compost yields were estimated based on residue-to-compost conversion ratios and nutrient application rates were calculated according to guidelines from the Land Development Department (LDD). The study also involved a survey of 30 local farmers to assess current composting practices, challenges and the feasibility of adopting composting as an alternative to synthetic fertilizers. The plant growth data were subjected to one-way analysis of variance (ANOVA) using SPSS (IBM SPSS Statistics Version 26.0). Duncan's multiple range test (DMRT) was used to separate treatment means at a significance level of $p \leq 0.05$. The coefficient of variation (C.V. %) was calculated to assess experimental consistency.

RESULTS AND DISCUSSION

Chemical characteristics of agricultural residues and resulting compost quality

The longkong peel exhibits a low C/N ratio (21.59), which promotes faster decomposition and its high nitrogen (1.90%) and potassium (3.46%) content make it highly suitable for composting (Table 1 and 2). This leads to the faster release of nutrients, thereby enhancing the soil fertility and plant growth (Nguyen *et al.,* 2024; Wong *et al.,* 2023). In contrast, cajeput bark has a very high C/N ratio (103.84) and hence slower decomposition and nutrient release. It has a high organic matter content (121.74%) and its slower breakdown provides nutrients over a more extended period, benefiting long-term soil fertility (Tan *et al.,* 2022; Suri *et al.,* 2023). The composting, of materials met the Thai Organic Fertilizer Standards, which ensure compliance with required pH, organic matter and macronutrient content (Table 3). This confirms their potential for use in agricultural applications (Sato *et al.,* 2025). Notably, longkong peel compost, despite its high nitrogen (2.59%) and potassium (2.96%) content had a high EC (6.67 dS m^{-1}), which might induce salt stress under certain conditions, especially in regions with low water availability or poor drainage (Chang *et al.,* 2024). Longkong peel compost being rich in nutrients, its salinity must be monitored when used in agricultural practices.

Influence of locally derived compost on plant growth and soil fertility

The application of compost derived from oil palm bunches, longkong peels and cajeput bark, significantly influenced plant growth, as evidenced by plant height and fresh biomass (Table 1). Oil palm bunch compost resulted in the tallest plants (145.75 cm) and the highest fresh weight (80.75 g). These values were statistically similar to those obtained with longkong peel compost, which produced plants measuring 138.35 cm in height and a fresh weight of 76.00 g. Cajeput bark compost promoted moderate growth, while the control (untreated soil) exhibited the lowest performance in both plant height (87.00 cm) and fresh weight (43.67 g). These results suggest that composts derived from oil palm bunches and longkong peels are particularly effective in enhancing plant growth compared to cajeput bark compost and control (Table 3).

These results are consistent with the findings of Lee *et al.* (2022), who reported that oil palm-based compost significantly improved plant height, biomass production and overall plant health. Their study highlighted that oil palm residues provide a balanced supply of essential nutrients such as nitrogen and potassium, which are critical for promoting vegetative growth. Similarly, Gupta *et al.* (2023) demonstrated that compost made from oil palm residues enhanced nutrient availability and improved soil health, leading to better plant growth. However, Nguyen *et al.* (2024) found that longkong peel-based composts, despite having high nitrogen and potassium content, could cause osmotic stress when the EC was high. In their study, longkong peel

Table 1: Chemical characteristics of raw plant residues.

Residue type	pH	EC (dS/m)	OM (%)	Total N (%)	P_2O_5 (%)	K_2O (%)	C/N ratio
Longkong peel	5.9	5.81	70.72	1.90	0.32	3.46	21.59
Cajeput bark	6.3	2.23	121.74	0.68	0.00	0.31	103.84
Oil palm bunch	6.4	2.01	87.81	1.43	0.16	0.10	35.62

Table 2: Chemical properties of composts derived from plant residues.

Compost type	pH	EC (dS/m)	OM (%)	Total N (%)	P_2O_5 (%)	K_2O (%)	C/N ratio
Longkong peel compost	7.8	6.67	88.87	2.59	1.41	2.96	19.46
Cajeput bark compost	6.9	3.80	89.26	1.78	1.96	1.31	29.09
Oil palm bunch compost	6.8	2.05	63.44	2.44	1.86	0.82	15.08

Note: Standard: Thai organic fertilizer standards (LDD, 2005)-pH 5.5-8.5; EC≤3 dS/m; OM≥35%; N≥1%; P_2O_5≥0.5%; K_2O≥0.5%; C/N≤20.

composts with lower EC values showed improved plant biomass. This indicates that while longkong peel is nutrient-rich, managing the EC during composting is crucial to avoid potential osmotic stress, which was observed in this study with high EC values limiting growth. In line with Zhao *et al.* (2023), cajeput bark composts, which tend to have relatively low nitrogen and potassium contents, were less effective in promoting plant growth, particularly during the early stages of plant development. Our study also confirmed that the lower nitrogen and potassium levels in cajeput bark compost contributed to its relatively lower growth performance compared to other composts, further emphasizing the importance of nutrient balance for optimal plant growth. Finally, as expected, the control treatment, which received no compost, exhibited the lowest growth values. This reinforces the critical role of compost in improving soil nutrient content, which in turn enhances plant productivity. This finding is consistent with Chen *et al.* (2022), who reported that untreated soils with insufficient organic amendments result in lower nutrient availability, leading to poor plant growth.

Fertilizer equivalence of composts and estimated nutrient contributions

The estimated fertilizer equivalence of the composts illustrates the substantial potential of local agricultural residues to meet plant nutrient demands. Among the three composts studied, longkong peel compost exhibited the highest nutrient equivalence, contributing approximately 610 tons of nitrogen (N), 332 tons of phosphorus (P_2O_5) and 698 tons of potassium (K_2O) annually. This is equivalent to 1,326 tons of urea, 922 tons of superphosphate and 1,163 tons of potash (Table 4). The high N and K content in longkong peel compost benefits the nutrient-demanding crops, aligning with previous studies on the effectiveness of fruit-based composts for improving soil fertility and promoting plant development (Nguyen *et al.,* 2024; Zhang *et al.,* 2023).

Table 3: Effect of different compost types on plant height and fresh weight of maize plant.

Treatment	Height (cm ± SD)	Fresh weight (g ± SD)
Control	87.00±3.75 ^{d}	43.67±2.50 ^{d}
Longkong peel compost	138.35±4.25 ^{ab}	76.00±3.40 ^{ab}
Cajeput bark compost	110.50±3.60 ^{c}	65.63±3.10 ^{c}
Oil palm bunch compost	145.75±5.10 ^{a}	80.75±4.00 ^{a}
C.V. (%)	13.62	15.59
F-test	**	**

Note: Values followed by the same letter are not significantly different at p<0.05 (DMRT); ** = p<0.01.

In contrast, cajeput bark compost and oil palm bunch compost added in quality of nutrients due to their lower nutrient contents and more limited biomass availability. Cajeput bark compost contributed an estimated 24 tons of N, 27 tons of P and 18 tons of K annually. Its relatively low equivalence is due to its slow decomposition rate, resulting in a gradual nutrient release and hence better suited for long-term soil fertility enhancement (Tan *et al.,* 2022; Suri *et al.,* 2023). Similarly, oil palm bunch compost, with its quicker decomposition due to a lower carbon-to-nitrogen (C/N) ratio, supplied only 9 tons of N, 8 tons of P and 3 tons of K per year and thus, its contribution alone is insufficient for intensive cropping systems (Lee *et al.,* 2022; Zhang *et al.,* 2023).

These composts can reduce the need for expensive chemical fertilizers, a critical factor for smallholder farmers in Thailand, where input costs are a major barrier to sustainable farming. Longkong peel compost, with its high nutrient equivalence, could notably reduce the need for synthetic nitrogen and potassium fertilizers, offering substantial cost-saving potential. In Indonesia, integrated composting of oil palm residues, such as empty fruit bunches and palm fronds, has been adopted at both smallholder and plantation levels. These practices enhance nutrient cycling and mitigate the environmental impact of residue burning (Yuliani *et al.,* 2023).

In China, large-scale composting is promoted under the national Green Development Strategy, especially in provinces like Shandong and Guangdong. Compost made from livestock manure and municipal organic waste is widely used to rehabilitate degraded soils and reduce environmental harm caused by chemical fertilizers.

In Thailand, aside from Narathiwat Province, other regions such as Chiang Mai and Nakhon Ratchasima have embraced composting with locally available materials including rice husks, fruit peels and livestock manure. These initiatives are supported by agricultural extension services and local government programs aimed at promoting organic farming.

In the Philippines, the Department of Agriculture supports composting programs under the Organic

Table 4: Estimated annual nutrient contributions and their equivalence to synthetic fertilizers.

Compost type	Compost (tons/year)	N (%)	P_2O_5 (%)	K_2O (%)	N (tons)	P (tons)	K (tons)	Equivalent fertilizer (tons)**
Longkong peel	23,568	2.59	1.41	2.96	610	332	698	1,326 (N), 922 (P), 1,163 (K)
Cajeput bark	1,356	1.78	1.96	1.31	24	27	18	52 (N), 75 (P),30 (K)
Oil palm bunch	423	2.44	1.86	0.82	9	8	3	20 (N), 21 (P), 5 (K)

Note: Compost type compost (tons/year) N (%) P_2O_5 (%) K_2O (%) N (tons) P (tons) K (tons) Equivalent Fertilizer (tons)**.

Table 5: Annual compost production and nutrient requirements for small holder farms in narathiwat province.

Crop type	Annual fertilizer requirements (tons/year)	Annual compost demand (tons/year)	Compost production (tons/year)	Shortfall (tons)
Rice	2,500	5,000	2,500	2,500
Fruit crops (longkong)	1,000	2,000	1,000	1,000
Vegetables	500	1,000	600	400

Agriculture Act of 2010, encouraging the use of coconut husks, banana stalks and animal waste to produce organic fertilizers. These efforts are intended to improve food security and soil health by minimizing chemical inputs.

Collectively, these examples illustrate that composting is not only a viable practice but also an integral part of national agricultural strategies across Asia. They align closely with this study's findings, which demonstrate that composts-such as those made from longkong peel-can effectively reduce reliance on chemical fertilizers, especially in regions rich in agricultural residues and in need of cost-effective, sustainable fertilization solutions.

Alignment of compost production with crop nutrient needs in sandy soils

Despite these efforts, the mismatch between compost supply and demand remains striking. As seen in Table 5, the amount of compost produced in Narathiwat Province (approximately 60,000 tons per year) falls far short of the needs of smallholder farmers. This shortfall could be addressed by increasing compost production capacity, improving composting practices and providing incentives for compost adoption among farmers. Moreover, integrating local plant residues like longkong peel, cajeput bark and oil palm bunches into a circular economy model could significantly contribute to the sustainability of agricultural practices in the region. However, this approach also faces challenges related to the logistics of collection, transportation and application in the fields.

Composting agricultural residues for sustainable fertilization: Contributions to SDGs

This study highlights the contributions of composting to sustainable agriculture in alignment with multiple SDGs, especially SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land). In SDG 2: Zero Hunger, composting improves soil fertility, enhancing crop resilience and ensuring food security, especially for smallholder farmers who rely on organic farming methods. SDG 12 (Responsible Consumption and Production) in getting adverted using local agricultural residues, composting contributes to reducing waste, promoting sustainable consumption practices and decreasing reliance on synthetic fertilizers. SDG 15 (Life on Land) The enhancement of soil health through composting improves land productivity, restores degraded soils and supports biodiversity, making a significant contribution to sustainable land management.

CONCLUSION

The potential of composting local agricultural residues, such as longkong peel, cajeput bark and oil palm bunch, as a sustainable alternative to chemical fertilizers in Narathiwat Province, Southern Thailand. The chemical properties of the composts indicated that these compost met the Thai Organic Fertilizer Standards, with longkong peel compost providing the highest nutrient equivalence. The impacts of these composts on plant growth were significant, with longkong peel compost showing the best results in terms of plant height and fresh weight, while cajeput bark compost and oil palm bunch compost had slower decomposition and poor growth benefits. The estimated fertilizer equivalence of the composts suggests that longkong peel compost could significantly reduce the need for synthetic fertilizers, providing substantial economic and environmental benefits. However, the high salinity of longkong peel compost requires careful management, especially in regions with limited water resources. Despite the clear benefits, the current production of compost in Narathiwat Province is insufficient to meet the nutrient demands of smallholder farmers. Addressing this gap requires an increase in compost production capacity and improved logistical systems for collection, transportation and application. Policies promoting compost adoption, including financial incentives and education programs for farmers, are essential to support the transition to sustainable fertilization practices. Finally, the use of local plant residues in composting aligns with multiple Sustainable Development Goals (SDGs), particularly those focused on zero hunger, responsible consumption and production and life on land. By enhancing soil fertility, promoting organic farming and reducing waste, composting agricultural residues offers a promising pathway for sustainable agriculture in Narathiwat Province and similar regions.

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Disclaimers

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Conflict of interest

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