



Improving the Efficiency of Vermicompost Production by Using a Two-Step Composting Process with Agricultural Waste Materials

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Abstract: This research aimed to improve the vermicompost production process by combining a two-step composting process with agricultural waste to enhance soil fertility, increase productivity, and reduce costs. The experiment was divided into three phases: Phase 1 tested the production of vermicompost using manure from cows, goats, and sheep. Cow manure (CM) was found to be the most suitable raw material due to its friability, ease of digestion, and high-quality fertilizer value. Phase 2 investigated the production of vermicompost using supplementary materials from local plants, including Azolla (AZ), Leucaena leaves (LL), and Palm leaves (PL), combined with five formulas of cow manure for growing kale. Formula 5, consisting of 75% Cow manure (CM), 15% Azolla (AZ), and 10% Palm leaves (PL) by weight, provided the highest nitrogen content at 852.57 ± 0.045 mg/kg. Finally, the growth of kale was studied using vermicompost from the second stage mixed with soil at a 1:1 ratio. Formula 7 (50% Vermicompost [CM+AZ+PL] and 50% NS) yielded the best kale growth, in terms of height, leaf width, weight, and fertility.

Keywords: Vermicompost; manure; agricultural waste materials; soil fertility; two-step composting process

1. Introduction

As the trend toward health and environmental awareness grows, agriculture plays a crucial role as a primary food producer. This has necessitated changes in agricultural practices to build consumer confidence in product safety and quality. However, modern agriculture faces problems of soil degradation and infertility due to the continued overuse of fertilizers and chemicals. This is a significant problem that impacts both the quantity and quality of agricultural products. Sustainable soil fertility improvement using agricultural waste materials is an attractive approach, such as compost from empty palm fruit bunches from the palm oil extraction industry and vermicompost from animal manures, a fertilizer derived from earthworms' decomposition. Vermicompost contains a balanced set of plant nutrients and beneficial microorganisms, helping to improve soil structure for optimal plant growth [1].

Azolla is a small aquatic fern that can reproduce rapidly. Azolla contains 21.4-28.5% protein, essential amino acids, and 4.6% nitrogen. Azolla can be used as food for animals such as chickens, ducks, geese, cows, goats, and pigs to reduce feed costs [2]. Dhaker et al. [3] reported that Azolla has a protein content of about 14-30% on a dry basis. Leucaena is an invasive plant that grows throughout Thailand. It is widely used as animal feed in Thailand because Leucaena leaves contain a high protein content of 25.91 percent. In addition, Leucaena leaves contain nitrogen (N) at 3.69%, phosphorus (P) at 0.20%, and potassium (K) at 1.889% [4]. Therefore, it is suitable for use as a growing material for leafy vegetables. Palm leaves are agricultural waste products high in organic matter. Palm leaves and trunks contain nutrients of 21% nitrogen, 7.36% phosphorus, and 22% potassium [5]. According to data from 2023, Thailand has an oil palm plantation area of 6,553,666 rai, with the southern region accounting for 5,644,219 rai (Ministry of Agriculture and Cooperatives, 2024). In 2024, Satun Province had a total area of 1,754,700 rai, with a productive area of 129,261 rai. Palm fronds are pruned every 15-20 days after the palm harvest, accounting for approximately 7.37% of the total area [6]. Palm leaves are, therefore, another option for use as fertilizer.

Researchers are interested in using Azolla(AZ), Leucaena leaves (LL), and Palm leaves (PL) as materials to enhance the efficiency of vermicompost, as these waste materials contain essential nutrients for plant growth. This study focused on the application of Azolla (AZ), Leucaena leaves (LL), and Palm leaves (PL) to enhance the efficiency of vermicompost produced from Cow manure (CM), Goat manure (GM), and Sheep manure (SM) from the “Thung Yai Saraphi Model Learning Center Farm” at Songkhla Rajabhat University, Satun Campus. While some of this animal manure is used as fertilizer in palm plantations, the researchers believe it has not been fully utilized. Using animal manure to produce vermicompost would enhance its efficiency, serving as a model for the value-added management of waste materials for interested farmers. This approach, based on the concept of “zero waste,” utilizes available resources to add value and reduce environmental problems. Furthermore, it generates new knowledge to develop high-quality organic fertilizers suitable for local agriculture, thereby enhancing economic, social, and environmental benefits through their integration.

2. Materials and Methods

2.1 Preparation of materials and equipment for raising earthworms

Azolla (AZ): Cultivate Azolla using cow dung in a pond 0.50 meters deep, 1.0 meters wide, and 10 meters long (with a water volume of 5.0 cubic meters). Add 50 kg of dry old cow dung and 10 kg of Azolla. Store the Azolla at 10-15 days old and allow it to stand for 30 minutes before use.

Leucaena Leaves (LL): Use only fresh Leucaena leaves.

Palm Leaves (PL): Chop fresh palm leaves into 2-3 centimeter pieces before use.

African Night Crawler (AF): African Night Crawler earthworms come from the “Thung Yai Saraphi Model Learning Center Farm” at Songkhla Rajabhat University, Satun Campus.

2.2 Animal manure preparation

Animal manure fermentation: Take dry and old animal manure, such as Cow manure (CM), Goat manure (GM), and Sheep manure (SM), and soak it in water in a cement pond (depth x width) 50x100 cm. for 3-5 days or until no bubbles are visible on the surface of the water, or to remove caustic soda. Then remove it, place it in a container to drain the water, and set it aside, ready for use.

2.3 Preparing containers for raising earthworms

Take a plastic basin with a diameter of 35 centimeters and poke about 15-20 holes in the bottom to allow water to drain easily. This helps prevent water from stagnating, which can create conditions unsuitable for earthworm decomposition.

2.4 Vermicompost production design, phase 1

Vermicompost production was conducted in a 35 cm diameter plastic basin using 200 g of AF (African Night Crawler) earthworms per basin. The bedding was filled to 3/4 of the basin (2,000 g/basin). The experiments were conducted with different beddings: Cow manure (CM), Goat manure (GM), and Sheep manure (SM) (Figure 1). Each experiment was conducted with 3 replications and watered thoroughly only

once on the first day. The humidity was at least 70%. The soil was placed in a shady, well-ventilated area. The results were recorded every 2 days. After 12 days, the vermicompost was sifted to separate the earthworms using a sieve with 2 mm holes. The vermicompost was then analyzed for chemical and physical properties. The best bedding for earthworm rearing was selected for further experiments in the second phase.

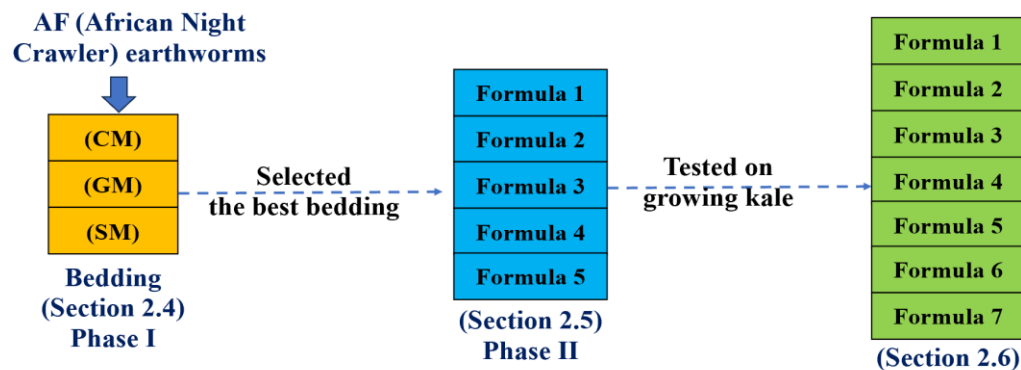


Figure 1. The vermicompost production process uses a two-step composting process combined with agricultural waste

2.5 Vermicompost production design, phase 2

Vermicompost production was conducted in a 35 cm diameter plastic basin using 200 g of AF (African Night Crawler) earthworms per basin. Bedding was filled to 3/4 of the basin or 2,000 g/basin. The best bedding from the phase 1 experiment (Section 2.4) was then tested with different beddings (Figure 1):

Formula 1: Best bedding, 75% + Azolla(AZ), 25%

Formula 2: Best bedding, 75% + Leucaena leaves (LL), 25%

Formula 3: Best bedding, 75% + Palm leaves (PL), 25%

Formula 4: Best bedding, 75% + Azolla(AZ), 15% + Leucaena leaves (LL), 10%

Formula 5: Best bedding, 75% + Azolla(AZ), 15% + Palm leaves (PL), 10%

Each experiment was conducted with 3 replications and watered thoroughly only once on the first day. The humidity was at least 70%. The soil was placed in a shady, well-ventilated area. The results were recorded every 2 days. After 12 days, the vermicompost was sifted to separate the earthworms using a sieve with 2 mm holes. The vermicompost was then analyzed for chemical and physical properties. All formulas were selected for the kale-growing experiment.

2.6 Tested on growing kale

The experiment was conducted by growing kale (*Brassica oleracea var. alboglabra*) in 10 x 20-inch growing bags, using soil in proportions according to the experimental formula (Section 2.5), with 3 replications per treatment (Figure 1).

Formula 1: Natural Soil (Control), 100%

Formula 2: Best bedding (Section 2.4), 50% + Natural Soil, 50% (Ratio 1: 1)

Formula 3: Formula 1 (Section 2.5), 50% + Natural Soil, 50% (Ratio 1: 1)

Formula 4: Formula 2 (Section 2.5), 50% + Natural Soil, 50% (Ratio 1: 1)

Formula 5: Formula 3 (Section 2.5), 50% + Natural Soil, 50% (Ratio 1: 1)

Formula 6: Formula 4 (Section 2.5), 50% + Natural Soil, 50% (Ratio 1: 1)

Formula 7: Formula 5 (Section 2.5), 50% + Natural Soil, 50% (Ratio 1: 1)

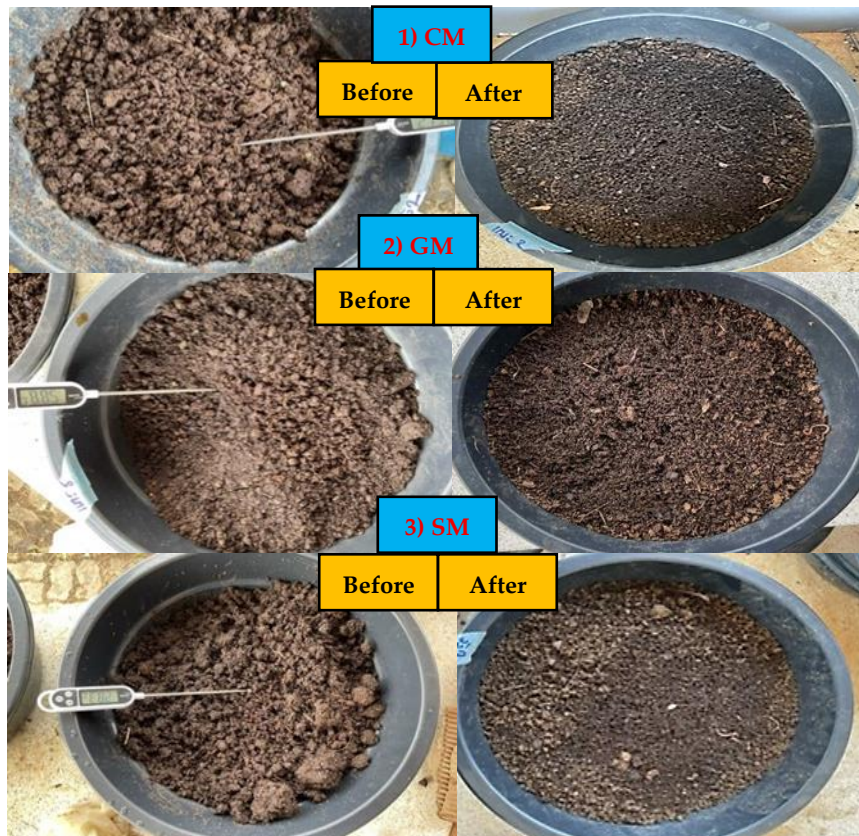
The plants were grown in slats that could receive 50% sunlight. The watering system was set to drip water twice a day, once in the morning and once in the evening, for 30 minutes each time. The results of the chemical and physical experiments were collected every 7 days for 8 weeks, and the kale was weighed for comparison in the final week.

2.7 Analytical methods

Soil composition analysis (NPK) was determined using the standard method [7]. Soil pH was measured using a soil pH meter (Shinwa PH Soil Meter, Japan). Data were analyzed by analysis of variance (ANOVA), and means were compared using Tukey's HSD test at $p < 0.05$.

3. Results and Discussion

3.1 Vermicompost production, phase 1



(A) Before producing vermicompost (B) After producing vermicompost (After 12 days)

Figure 2. Vermicompost production, phase 1; (CM = Cow manure, GM = Goat manure, SM = Sheep manure)

Cow manure (CM), Goat manure (GM), and Sheep manure (SM) were clearly different after 12 days of earthworm rearing. The CM fertilizer was friable, smooth, and consistent, with no animal waste residue, as shown in Figure 2. This is because earthworm intestines harbor microorganisms that can decompose hemicellulose, such as *Bacillus subtilis* and *Cellulomonas spp.* These microorganisms produce hemicellulase enzymes that can break down the polysaccharide structure in plant cell walls. This results in rapid, highly efficient digestion of organic matter [8], [9]. In addition, it was found that the NPK value of formula CM significantly increased, with nitrogen (N) increasing from 146 to 536 mg/kg, phosphorus (P) rising from 48 to 498 mg/kg, and potassium (K) increasing from 200 to 572 mg/kg, as shown in Figure 3. Meanwhile, Goat manure (GM) and Sheep manure (SM) still contained undigested animal waste residues, especially in the form of hard pellets, a characteristic of both types of animal waste, as shown in Figure 3. Due to the compact structure of the manure and its high coarse fiber content, microorganisms and earthworms cannot readily access the organic matter within. Therefore, both types of manure should be finely ground to facilitate decomposition, and increase the surface area exposed to microbial enzymes. Anand yawati et al. [10] reported that unground GM and SM took longer to decompose and produced lower fertilizer quality than ground GM and SM before entering the vermicompost system, as the granular form of the manure limits the movement of microorganisms and earthworms and tends to accumulate undigested manure debris in the system.

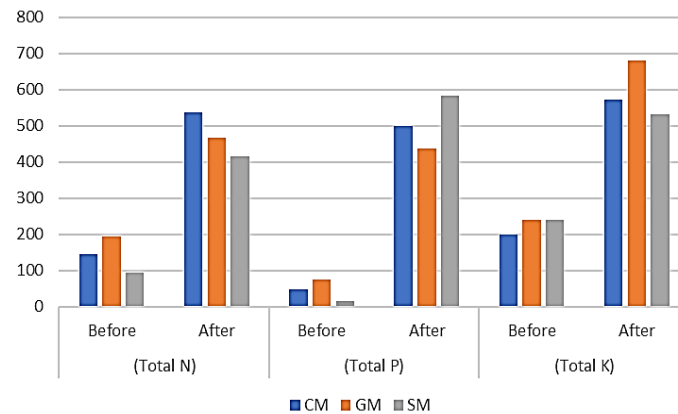


Figure 3. Compare NPK values of vermicompost production, phase 1

When all the vermicompost formulas from step 1 were analyzed for their N, P, and K chemical composition, the results were consistent with those of the physical experiments. This is because goat and sheep manure are hard pellets and more difficult to decompose than cow manure. As a result, the vermicompost produced from cow manure had higher N, P, and K values than those produced from sheep and goat manure. The vermicompost produced from cow manure had N, P, and K values of 536, 498, and 572 mg/kg, respectively, as shown in Figures 2 and 3. Cow manure (CM) was therefore selected for further experiments in step 2 (phase 2).

3.2 Vermicompost production, phase 2

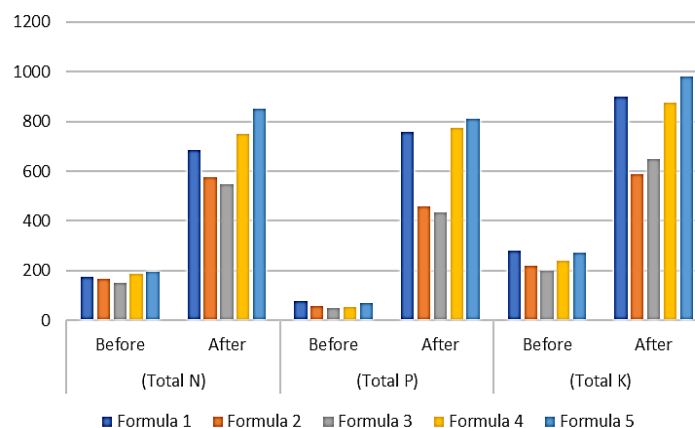


Figure 4. Compare NPK values of vermicompost production, phase 2

From the experiment on the production of vermicompost using cow dung for 12 days, using 3 types of local plant waste materials as supplementary materials, namely, Azolla (AZ), Leucaena leaves (LL) and, Palm leaves (PL), according to the experimental formula 1: 75% CM: 25% AZ; experimental formula 2: 75% CM: 25% LL; experimental formula 3: 75% CM: 25% PL; experimental formula 4: 75% CM: 15% AZ: 10% LL; and experimental formula 5: 75% CM: 15% AZ: 10% PL. In each experimental formula, the decomposition efficiency of the earthworms differs, as shown in Figure 5. In Formula 1, which consisted of 75% CM and 25% AZ, earthworms decomposed Azolla efficiently. Since Azolla contains approximately 10–15% lignin, which is at an optimum level for decomposition [11],[12], it also contains approximately 10–15% cellulose by dry weight, as it is an aquatic plant with a soft, easily digested structure [13]. It contains approximately $11.11 \pm 0.29\%$ hemicellulose on a dry-weight basis, which is considered relatively low. Due to Azolla's soft structure, it is conducive to earthworm decomposition [14]. The number of earthworms increased from 200 g to 226 g after 12 days, indicating that Azolla is suitable for incorporation into the vermicompost production process. In addition, the NPK value of Formula 1 was found to increase significantly, with nitrogen (N) increasing from 175 to 685 mg/kg, phosphorus (P) increasing from 78 to 758 mg/kg, and potassium (K) increasing from 280 to

898 mg/kg, as shown in Figure 4. Formulas 2 and 3, which used *Leucaena* leaves (LL) and palm leaves (PL) as supplementary materials in the vermicompost production process. It was found that earthworms could digest only some of the materials. In formula 3, which used 25% palm leaves from the initial amount of 1 kilogram, after 13 days of digestion, 900 grams of palm leaf scraps remained, indicating a low digestion rate. Meanwhile, in formula 2, which used 25% *Leucaena* leaves (LL) from an initial amount of 350 grams, approximately 330 grams of *Leucaena* leaf scraps remained, almost the same amount, reflecting the low decomposition rate of earthworms towards both types of materials, as shown in Figure 5. In terms of the number of earthworms after the experiment, it was found that in formula 3 (Palm leaves, PL), the number of earthworms decreased from 200 grams to 160 grams, while in formula 2 (*Leucaena* leaves, LL), the number of earthworms decreased to only 94 grams, which is the lowest value. The important factors affecting the digestion of oil palm leaves by earthworms were found to be the composition of cellulose, hemicellulose, and lignin, with oil palm fronds having a higher lignin content. On average, it is 17–25% of the dry weight, making it more suitable as a structural material in compost piles than as a direct animal feed [15]. Generally, earthworms can decompose organic materials containing lignin to about 15–20% of the organic content during the vermicomposting process. Because lignin has a complex structure and is resistant to decomposition, earthworms themselves do not have enzymes that can directly digest lignin. Therefore, they need to rely on certain microorganisms to help decompose it first [16]. Oil palm leaves are considered a high-fiber material. It was found that cellulose ranged from 35–45% [15]. Earthworms can decompose materials with a cellulosic structure to a maximum of 30–40% of the dry weight of the composted material. If it exceeds this amount, it will slow down the fermentation process and reduce the efficiency of the earthworms [15]. Oil palm leaves have an average hemicellulose content of about 20–25% of the dry weight, which is common in many biomass materials and is suitable for composting as fertilizer or bioenergy [13]. Earthworms can decompose objects with a hemicellulose structure, not more than about 40–50% of the dry weight of the materials used in composting. Earthworms rely on microorganisms in their intestines, together with microorganisms in the materials, to help decompose hemicellulose molecules into simple sugars [16]. In *Leucaena leucocephala* leaves, although they are high in protein, they contain an important non-protein amino acid called Mimosine, which can account for 2–6% of the dry weight of the leaves. This substance, when converted to 3,4-dihydroxypyridine (3,4-DHP), disrupts the function of the earthworm's intestinal microflora, causing the earthworm to grow slowly, reduce reproductive rate, and, in some cases, even die if taken in large quantities [18]. After 12 days of cultivation, all formulas of worm castings were sifted using a 2 mm sieve. The worm castings were then tested on kale cultivation.

3.3 Efficiency of vermicompost test results with kale cultivation

From an 8-week experiment, kale was grown using seven different fertilizer formulas from section 2.7 (Section 3.2): Formula 1, 100% Natural Soil (NS)(Control); Formula 2, 50% Vermicompost (CM) and 50%NS; Formula 3, 50% Vermicompost (CM+AZ) and 50%NS; Formula 4, 50% Vermicompost (CM+LL) and 50%NS; Formula 5, 50% Vermicompost (CM+PL) and 50%NS; Formula 6, 50% Vermicompost (CM+AZ+LL) and 50%NS; and Formula 7, 50% Vermicompost (CM+AZ+PL) and 50%NS. In the first week, kale in all formulas showed similar initial growth patterns, with an average height of approximately 1 centimeter and an average width of 1 centimeter, as shown in Figure 6. This indicates that environmental conditions do not significantly affect the initial germination stage. By the second week, kale in Formula 1 had grown significantly, reaching an average height of 3 centimeters and a width of 2 centimeters. Formulas 3, 4, 5, 6, and 7 showed low to moderate growth, averaging 1.5–2.5 centimeters. During weeks 3 to 4, kale in Formula 4 reached an average height of 5 centimeters and a width of 4 centimeters, followed by Formulas 6, 7, 2, 3, 5, and 1, respectively, as shown in Figure 7. *Leucaena* leaves (LL) are rich in nutrients, including nitrogen and phosphorus (P), which are key factors in the production of proteins and ATP essential for plant cell growth [19], [20].



(A) Before producing vermicompost (B) After producing vermicompost (After 12 days)
Figure 5. Vermicompost production, phase 2;

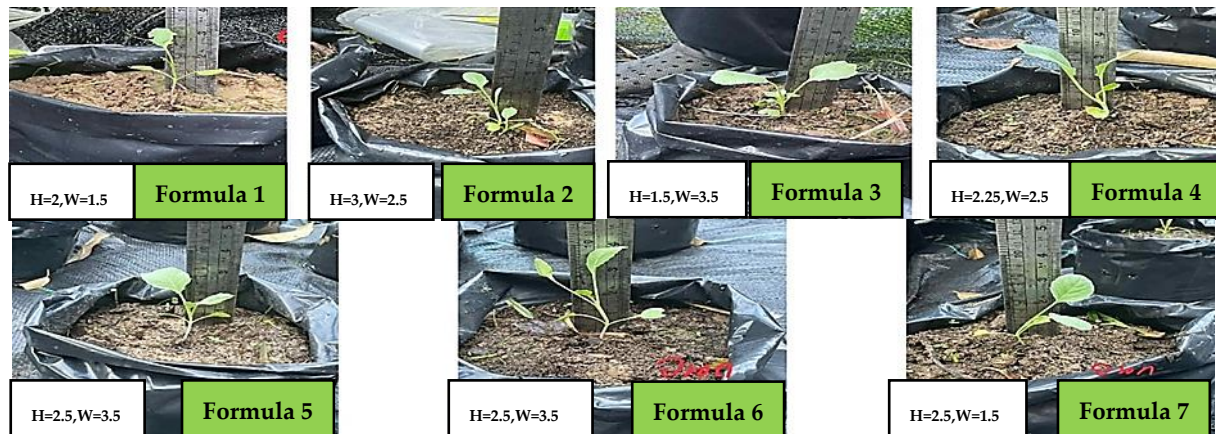


Figure 6. Efficiency of vermicompost test results with kale cultivation, 1-3 weeks (H=height, cm; W=Width, cm.)

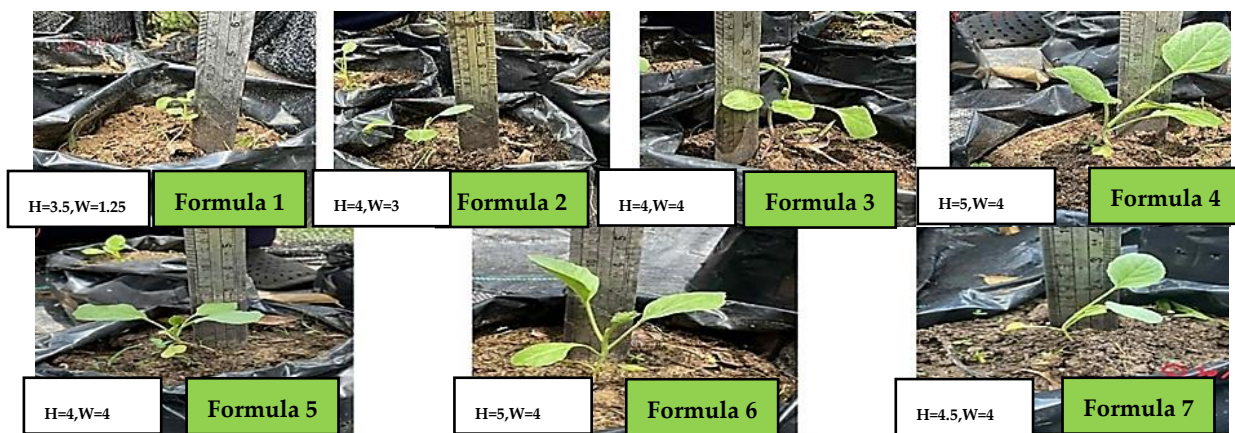


Figure 7. Efficiency of vermicompost test results with kale cultivation, 4 weeks (H=height, cm; W=Width, cm.)

By the fifth week, kale in Formula 2 reached an average height of 6 centimeters and a width of 4.5 centimeters, followed by experimental Formulas 4, 6, 3, 5, 7, and 1, respectively, as shown in Figure 8. Cow manure (CM) contains a high nitrogen content in a form that is easily absorbed by plants [21], thus stimulating rapid stem and leaf cell development in the initial stages.

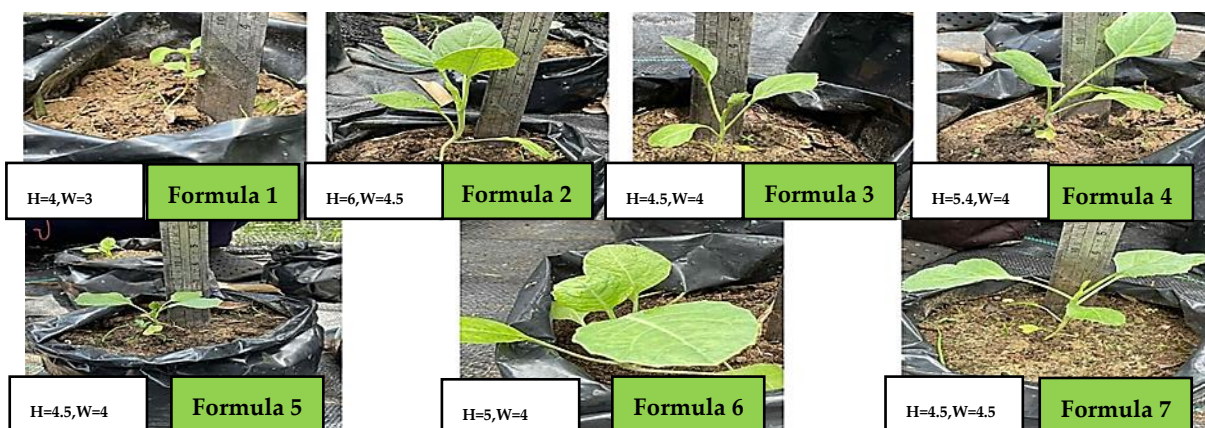


Figure 8. Efficiency of vermicompost test results with kale cultivation, 5 weeks (H=height, cm; W=Width, cm.)

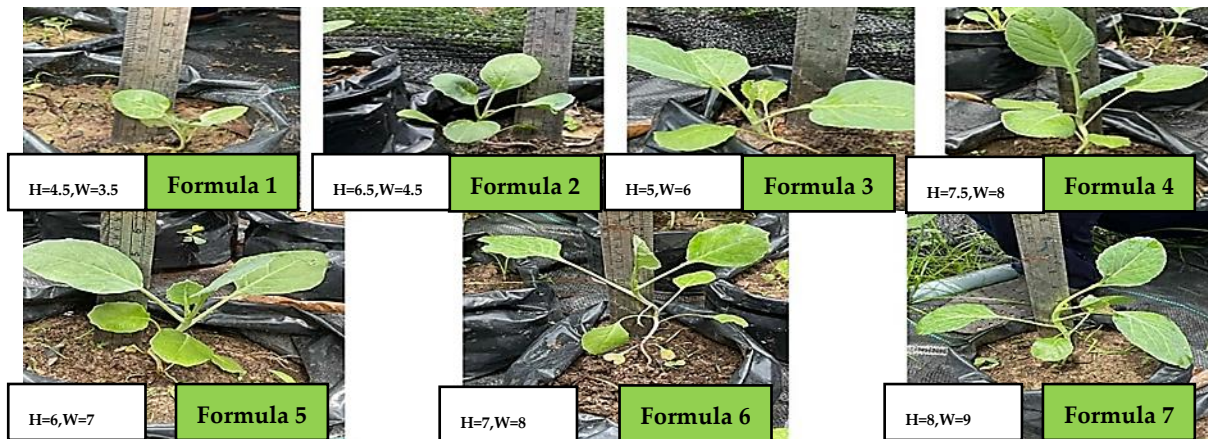


Figure 9. Efficiency of vermicompost test results with kale cultivation, 6 weeks (H=height, cm; W=Width, cm.)

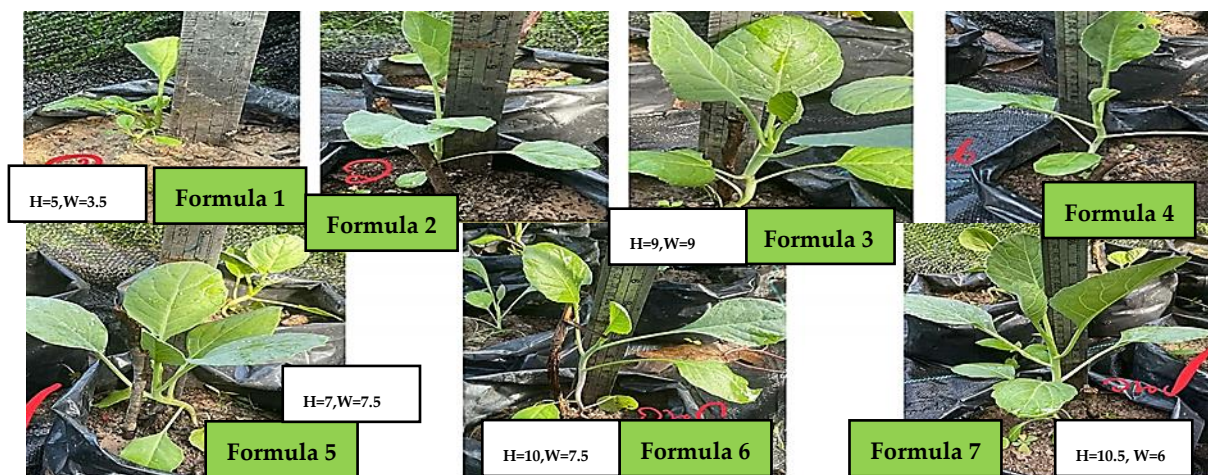


Figure 10. Efficiency of vermicompost test results with kale cultivation, 7 weeks (H=height, cm; W=Width, cm.)

From weeks 6 to 8, Formula 7 showed the highest average height growth rate among the other formulas, steadily increasing to 11 centimeters and an average width of 15 centimeters by week 8, as shown in Figures 9-11. This is the highest of all formulas. In comparison, Formulas 6, 3, and 4 followed, each with an average height of 9.5–10 centimeters. By contrast, Formula 1 had the lowest average height growth rate at 6.5 centimeters and an average width of only 5 centimeters. The superiority of Formula 7 may be due to its balanced N and K nutrition from Azolla (high N) and palm leaves (high K), which increased photosynthetic efficiency and stimulated water and nutrient transport within the plant [22], [23]. Furthermore, in terms of the number of leaves, soil formula 7 had the highest average, at 6.75 leaves. This was followed by formula 3 with an average of 6.625 leaves, while formula 1 had the least average number of leaves at 4.625 leaves. From the above data, it can be observed that formula 7 consistently promotes the growth in the number of kale leaves each week, especially in the 8th week, which had an average of 10 leaves, as shown in Figure 11. Notably, these experimental results are consistent with the research of Jiraporn et al. [24], which found that plant formulas with a complete and balanced nutrient composition effectively promote plant photosynthesis, resulting in increased leaf number and overall plant growth. An 8-week experiment on kale revealed significant differences in kale weight per plant across the formulas. Formulas 1 and 2 had significantly lower weights, approximately 5-10 grams, while Formulas 3, 4, 5, and 6 had weights of approximately 20-25 grams. Formula 7, on the other hand, weighed 45.07 grams, demonstrating the potential of each fertilizer formula (Figure 12). For commercial cultivation, weight may vary depending on the variety, growing method, environment, and harvest time [25].

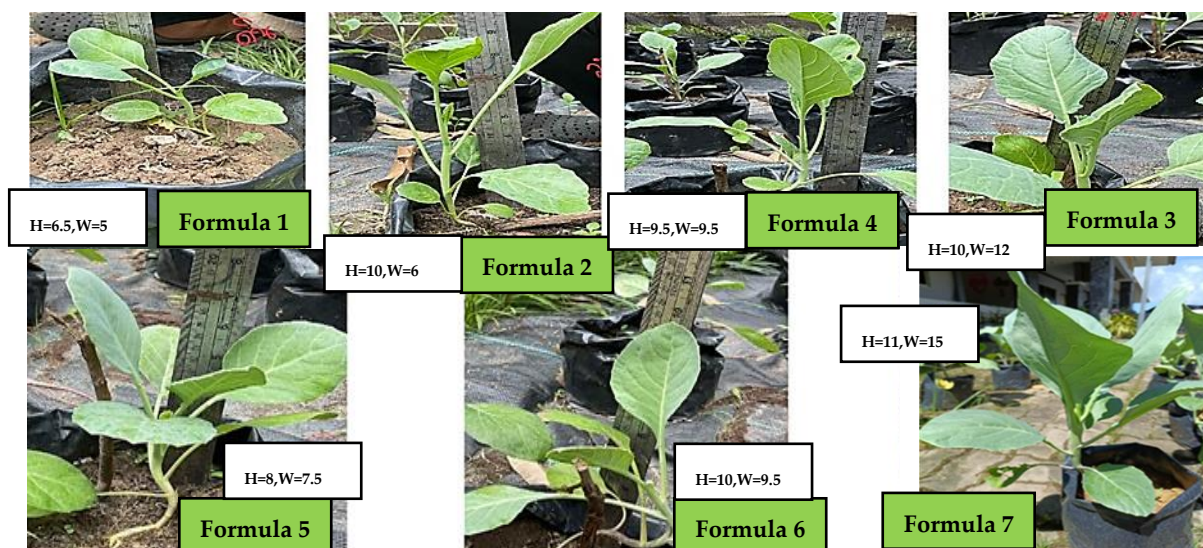


Figure 11. Efficiency of vermicompost test results with kale cultivation, 8 weeks (H=height, cm; W=Width, cm.)

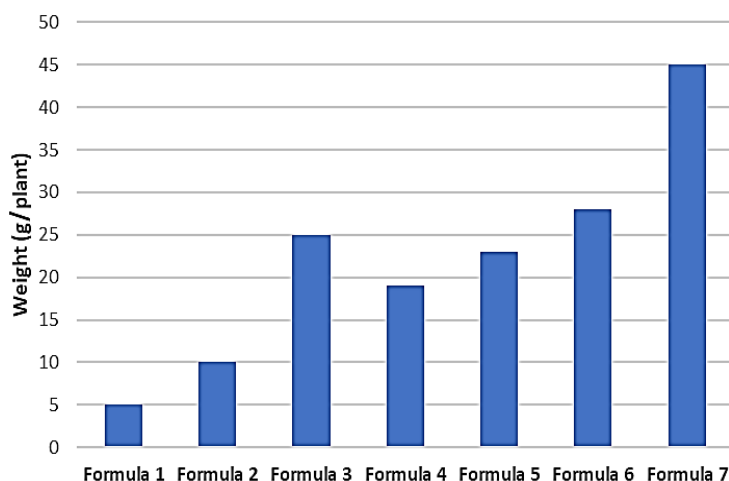


Figure 12. Weight of kale at 8 weeks of cultivation

Table 1. Effect of fertilizer formulas on yields of kale

Treatment	Yield (g plant ⁻¹)
Formula 7	45.07 ± 0.21 a
Formula 6	28.00 ± 0.20 b
Formula 3	24.90 ± 0.36 c
Formula 5	23.17 ± 0.38 c
Formula 4	19.10 ± 0.36 d
Formula 2	10.10 ± 0.36 e
Formula 1	4.87 ± 0.32 f

***Values are presented as mean ± standard deviation (n = 3). Means followed by different letters within the same column are significantly different at $p < 0.05$, as determined by analysis of variance (ANOVA) followed by Tukey's HSD test. The coefficient of variation (CV) ranged from 0.46 to 6.60%.

The experimental results showed that the nutrient formula had a significant effect on kale growth and yield ($p < 0.05$). Formula 7 yielded the highest weight (45.07 ± 0.21 g/plant) and differed significantly from the other formulas, reflecting that the nutrient ratio in this formula was optimal for the plant's needs during the growth phase, as shown in Table 1. The high yield of formula 7 may be explained by the balance of major nutrients: nitrogen (N), phosphorus (P), and potassium (K), which play crucial roles in leaf formation, root

development, and nutrient translocation within the plant. Nitrogen promotes stem and leaf growth, the edible parts of kale, while potassium enhances photosynthesis efficiency and nutrient accumulation, resulting in a significant increase in plant weight. Conversely, formulas 6 and 3, which yielded the next highest results, had moderate weight and differed significantly from formula 7, indicating that the nutrient ratios may not have been as optimal as those in formula 7, although they were sufficient for some level of growth. Formulas 1 and 2, which yielded the lowest, may have resulted from insufficient or unbalanced nutrient supply, limiting plant growth. Relative variance (CV) values ranging from 0.46 to 6.60% indicate high experimental accuracy and data consistency, enhancing the reliability of experimental results and statistical analysis. Furthermore, low standard deviations (SD) across all formulas reflect the consistency of yields within each experimental set.

3.4 Economic value

Table 2. Cost of production of vermicompost

Experiments	CM (g)	AZ (g)	LL (g)	PL (g)	Cost (bath/ basin)	Cost (bath/kg)
CM 100%	2,000	0	0	0	10	5.00
Formula 1: CM, 75% + AZ, 25%	1,500	500	0	0	9.00	4.50
Formula 2: CM, 75% + LL, 25%	1,500	0	350	0	6.00	3.00
Formula 3: CM, 75% + PL, 25%	1,500	0	0	1,000	6.30	3.15
Formula 4: CM, 75% + AZ, 15% + LL, 10%	1,500	360	140	0	13.20	6.60
Formula 5: CM, 75% + AZ, 15% + PL, 10%	1,500	360	0	400	6.12	3.06

Note: No cost of earthworms (AF)

A study of the production costs of vermicompost using local plant-based supplements, including azolla, leucaena leaves, and palm leaves, found that Formula 1 (75% cow dung: 25% azolla) had a production cost of 9 baht per kilogram (Table 2). This is based on the market price of 20 baht per kilogram of azolla. However, using azolla grown from homegrown farms could significantly reduce costs. Leucaena and palm leaves, agricultural waste readily available in the community and inexpensive or almost unnecessary to purchase, can reduce costs similarly to the azolla formula. A cost comparison is shown in Table 2, indicating that formulas containing all plant-based supplements have lower production costs than those containing cow dung alone. Furthermore, using azolla grown from the market significantly increases costs compared to farm-grown production. Therefore, homegrown azolla cultivation is a sustainable option that reduces costs and improves productivity. From an environmental perspective, using supplements such as azolla, leucaena leaves, and palm leaves in the vermicompost production process not only reduces production costs but also adds value to agricultural waste. This helps reduce biological waste and promotes efficient resource use. Furthermore, it can be developed into a supplementary occupation for local farmers, generating sustainable income and job security.

4. Conclusions

A study of vermicompost production using different supplementary materials, including azolla, leucaena leaves, and palm leaves, found that Formula 7: 50% Vermicompost (CM+AZ+PL) and 50%NS yielded the best results for kale growth, both in terms of average height and plant width. This demonstrates the effectiveness of the supplementary materials in terms of quality and growth-promoting ability. Compared to Formula 5, which used 50% Vermicompost (CM+PL) and 50%NS, significantly increased yield, demonstrating synergistic effects between Azolla (AZ) and Palm leaves (PL). Meanwhile, in Formula 6, 50% Vermicompost (CM+AZ+LL) and 50%NS showed no significant difference compared to the use of Azolla (AZ) or Leucaena leaves (LL) alone (Experiments 2 and 3), indicating that Azolla (AZ) and Leucaena leaves (LL), when combined, do not significantly synergize. The qualitative conclusions are: 1) Using azolla together with palm leaves has a high potential for producing vermicompost that can enhance kale growth. 2) Different supplementary materials clearly affect fertilizer quality and plant growth, with synergistic or non-synergistic effects depending on the type of supplementary materials used.

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