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Multi-Component Composting of Agricultural By-Products Improves Compost Quality and Effects on the Growth and Yield of Cucumber

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ABSTRACT

Agricultural by-products can be converted into organic fertilizers through thermophilic composting process. In this study, four combinations of different agricultural by-product materials were composted to find a mixing treatment that improves thermophilic composting process and produces good quality compost. Four treatments included M1 (straw, chicken manure, elephant grass), M2 (straw, chicken manure, cabbage leaves), M3 (straw, cow manure, elephant grass) and M4 (straw, cow manure, cabbage leaves). Compost phytotoxicity was tested on Brassica and Spinach seeds through germination tests. Experiment of evaluating the effects of these compost combined with inorganic nitrogen fertilizer on the growth and yield of cucumber was also conducted. Research results indicated that using agricultural by-product composting materials including straw, chicken manure with elephant grass or cabbage leaves gave better temperature behavior, compost quality and volume than others. Composts of the treatments are considered free of toxicity because they all gave a germination of over 80%. Applying 70% composts of M1 or M2 combining with chemical nitrogen fertilizer replaced for 30% of nitrogen in compost to soil significantly increased the growth and yield of cucumber. The agricultural by-products should thus be converted into nutritious compost which is healthy food feeding soil and crops to contribute to closing the food chain in circular agriculture, protecting environment, and developing agriculture production sustainably.

Keywords: agricultural by-product, compost application, cucumber.

INTRODUCTION

Agricultural production has been generated the large quantity of agricultural residues and wastes. Arora et al. (2023) reported, the production of agricultural by-products worldwide reaches billions of tons. According to Nguyen et al. (2020) total crop residues and by-products produced from agricultural activities in Vietnam were estimated at 100 million tons per year. These waste sources are not used well, when almost of them are treated by burning or are disposed on the field without any treatment, causing to burden to the environment. However, agricultural by-products have a huge potential to be utilized as the value-added products. Through composting, the recycled organic wastes are utilized as soil organic amendments, which contain a highly valuable source of organic matter as well as nutrient elements, which are able to meet the crop nutrient requirements, increase soil organic matter and enhance soil fertility, as well as reduce the environmental pollution (Kaboré et al., 2010; Bian et al., 2019; Nguyen et al., 2020; Waqas et al., 2023; Al-Tawarah et al., 2024). Nowadays, composting is an efficient and environment-friendly method for managing agricultural wastes because of its convenience and cost-effectiveness (Bian et al., 2019; Aylaj and Adani, 2023).

The positive influences of composts on the soil and crops are dependent on the quality of compost, which are strongly affected by composting setup parameters consisting of temperature in thermal phases, oxygen, moisture, C/N ratio, pH level (Argun et al., 2017; Muscolo et al., 2018; Bian et al., 2019; Sayara et al., 2020). Soe et al. (2022) reported that the changes of these parameters within composting pile significantly varied due to different raw materials used for composting. According to Bian et al. (2019) the composts with multiple components have been recommended due to higher efficiency of utilizing various types of agricultural wastes, which give better compost quality. Muscolo et al. (2018) showed that the composts could be mature despite of the types of initial materials, but their beneficial effects on the soil and crops were significantly different and mostly dependent on the chemical compositions of raw materials sources. It was agreed by Argun et al. (2017), Muscolo et al. (2018), Nguyen et al. (2020), Sayara et al. (2020), who concluded that quality of compost products primarily depends on the origins of raw components, their nutritional composition and their mixing proportion, in particular C/N ratio of compost mixture, rather than the composting setup parameters. Argun et al. (2017) and Soe et al. (2022) showed that the proper proportion between starting materials to gain the suitable ratio C/N is the most important for composting procedure to obtain high-quality compost products. Azim et al. (2018) revealed longer time and lower rate of decomposition of raw materials under high C/N; and the low C/N can cause nitrogen losses due to high temperature of composting pile. The initial C/N ratio of composting pile materials of thermophilic composting process should be from 20 to 30, and 26 is optimal (Ji et al., 2023). On the other hand, Soe et al. (2022) reported the variation of temperature in composting process, the volume and weight reductions, the bulk density, electrical conductivity (EC) of compost products depending on the types of initial materials used.

Phytotoxicity is an important aspect when evaluating compost quality. Low-quality composts can cause adverse impact on seed germination, inhibit plant growth and development due to the ability of producing the phytotoxic compounds (Selim et al., 2012). For detecting phytotoxicity of compost, germination index (GI) is the common method used because of its low cost, short term and being suitable for all substrates (Siles-Castellano et al., 2020). GI can be determined based on germination rate and root elongation of plant seeds, with the value of less than 50% showing high phytotoxicity of compost products, the value higher than 80% showing mature compost and the value higher than 100% resulting in phytostimulant effect (Siles-Castellano et al., 2020). According to Selim et al. (2012), Siles-Castellano et al. (2020), Aylaj and Adani (2023), during the composting time, GI gradually increase along with the elimination of phytotoxic compounds from the compost pile. GI is clearly related with the stability and maturity of composts, which are significantly varied according to the initial mixing components, composting time, composting methods and other management techniques (turning number, moisture) used during the composting process (Aylaj and Adani, 2023; Siles-Castellano et al., 2020).

Typical agricultural wastes in Vietnam include fresh vegetable residues, rice straw and livestock manure, which are locally available for composting. Livestock manure is characterized by high density and moisture content, lower C/N ratio (Li et al., 2008; Qian et al., 2014), and large amount of nutrients, especially nitrogen for microorganisms in composting. Adding poultry manure leads to the enhancement of water and nutrient holding capacity of the soil, as well as the reduction of the composting time (Soe et al., 2022). Green waste from crops has been reported as another proper co-substrate for compost, which helps to increase the nitrogen content in compost products because of their low C/N ratio, high moisture and

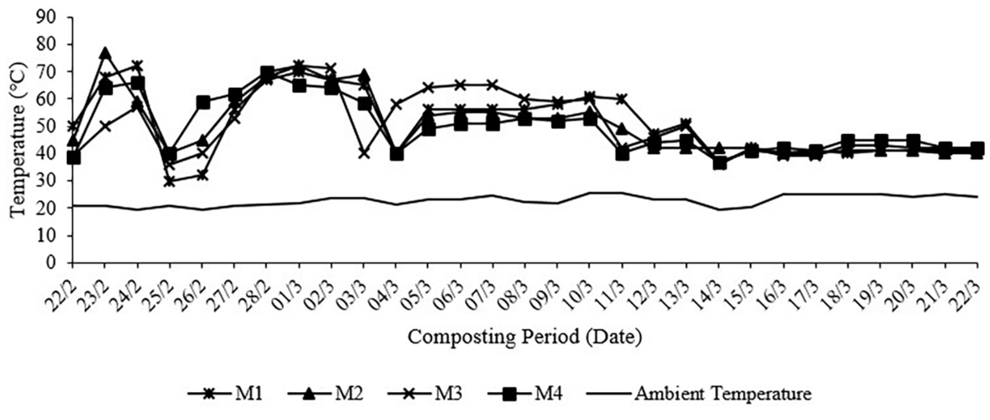

Figure 1. Daily temperature of composting piles

biodegradability (Bian et al., 2019; Pandebesie et al., 2022). In contrast, rice straw is characterized by low density, low moisture and high C/N (Li et al., 2008; Qian et al., 2014). Mixing the available raw materials in appropriate proportion can successfully optimize the composting process (Bian et al., 2019), provide proper moisture content, more balanced nutrients for microorganism to carry out the composting process and result in high-quality compost (Li et al., 2008; Qian et al., 2014). Assessing composting quality according to the initial mixing components of compost mixture is necessary to gain high-quality compost products, which is fit for agricultural purposes.

From the abovementioned considerations, this research was conducted to evaluate the influence of starting raw materials with different chemical characteristics to the quality of compost products as well as assess the effect of compost products on growth and yield of some common crops in Vietnam.

MATERIALS AND METHODS

Experiment site, raw agricultural by-product materials and cultivation practices

This study was conducted in the research field at Vietnam National University of Agriculture in Vietnam in the Spring 2023 (21°0’ North, 105°55’East). The chemical properties of the experimental soil included total nitrogen content (0.11%), total phosphorus content (0.2%), total potassium content (2.77%), available nitrogen (1.4 mg 100 g^{-1} of soil), available phosphorous (8.4 mg 100 g^{-1} of soil), organic matter (2.22%), and pH (7.91). This region climate is tropical. During the experiment, the average air temperature and humidity in February, March, April, and May in 2023 were 20.0 °C, 22.2 °C, 24.90 °C, 27.8 °C and 82.7%, 82.7%, 87.0%, 81.3% respectively. Composting materials were agricultural by-products including rice straw, chicken manure, cow manure, elephant grass and cabbage leaves. Dried rice straw and fresh cabbage leaves were received from farmer cooperative. Chicken manure and cow manure were collected from chicken and cow farms. Fresh elephant grass was harvested and cut into 10 cm of pieces from the research field of Vietnam National University of Agriculture. The characteristics and chemical composition of the materials are presented in Table 1.

Chemical nitrogen fertilizer used in experiment 2 was Urea nitrogen (N) fertilizer with a N content of 46%. The cucumber variety was Lam Yen variety from Know You company, Taiwan. Fifteen-day seedlings were transplanted with the row-to-row space of 30 cm and plant-to-plant space of 25 cm. Two rows were grown on the seed bed with 1.2 m wide and 40 cm height.

Experimental design and study parameters

Experiment 1 – effect of agricultural by-products as composting materials on the quality of thermophilic compost

A single factor experiment with the treatments of different combinations of agricultural by-product materials with M1 (rice straw, chicken manure, elephant grass), M2 (rice straw, chicken manure, cabbage leaves), M3 (rice straw, cow manure, elephant grass) and M4 (rice straw, cow manure, cabbage leaves) was conducted. Each treatment included 3 replication composting piles. Each 1.0 m^3 composting pile was covered around by the steel mesh cage (a mesh of 5×5 cm, a cage had 1.2 m in height and 3.6 m diameter). The materials were arranged in sequential layers of straw, green grass or cabbage leaves, and chicken manure or cow manure until the top of the cage. The weight of each material in each composting pile was shown in Table 2.

The composting pile was turned when the pile temperature reaches 55–65 °C for 3 consecutive days, or 65–70 °C for 2 consecutive days, or

Table 1. Properties of agricultural by-products used for composting

Properties	Rice straw	Cow manure	Chicken manure	*Pennisetum purpureum* (Elephant grass)	Cabbage leaf
Organic matter, OM (%)	86.20	86.70	78.30	85.90	77.40
Organic carbon OC (%)	47.89	48.17	43.50	47.72	43.00
Total Nitrogen Content, Nt (%)	0.82	1.96	2.67	2.25	3.21
C/N	58.40	24.58	16.29	21.21	13.40
Moisture (%)	12.00	77.32	17.64	82.00	70.00

Table 2. Components of composting piles

Treatments	Components					Total weight (kg)	C/N
	Rice straw (kg)	Cow manure (kg)	Chicken manure (kg)	*Pennisetum purpureum* (Elephant grass) (kg)	Cabbage leaf (kg)		
M1	33	-	15	60	-	108	30
M2	39	-	12	-	66	117	25
M3	21	60	-	60	-	141	30
M4	36	66	-	-	61	163	27

70–72 °C for 1 day. If the pile is above 72 °C, it was turned over immediately and checked regularly. The composting piles were also turned when it was too wet or too dry to ensure 50–60% of moisture. The total nitrogen content (TN, Kjeldahl method), total organic matter content (OM, Walkley – Black method) and organic carbon content (OC) of composting materials was analyzed before preparing the compost. The compost properties were measured 45 days after composting, including pH (pH meter method), TN (Kjeldahl method), total phosphorous content (TP, Spectrophotometer method), total potassium content (TK, Flame photometer method), OM (Walkley – Black method). Compost samples were taken from each composting pile, placed in plastic bags. Temperature was measured using a Reotemp thermometer and recorded at least once a day during the composting period. The thermometer tip was placed in the center area of the composting pile. Compost phytotoxicity was tested by using a germination test as in Mitelut and Popa (2011) and Warman (1999) at 45 days after composting. Ten grams of air-dried compost was added to 100 ml of distilled water to prepare a mixture with the ratio 1:10 (w/v). After 30 minutes of shaking, the compost extract was collected by filtering the mixture. *Spinacia oleracea* L. and *Brassica juncea* (L.) Czern seeds were used for the germination test. Ten seeds were placed in a petri dish with a filter paper and 10 ml of the compost extract. Distilled water was used in the control treatment. The test was replicated 3 times at room temperature. Germinated seeds were counted after 7 days of incubation. The root and shoot lengths of germinated seed were also measured (Mitelut and Popa, 2011; Warman, 1999). Germination index (GI) was calculated according to the formula (Chen et al., 2010): GI (%)= ((%Seed Germination×Root Length of Treatment)×100) / (%Seed Germination×Root Length of Control).

Experiment 2 – Effect of combining application of compost and chemical nitrogen (N) fertilizer on the growth and yield of cucumber

A single factor experiment was arranged according to the randomized complete block design with 3 replications. The experimental fertilization treatments included P1 (70% of M1 compost combining with chemical N fertilizer replaced for 30% of N in M1 compost), P2 (70% of M2 compost combining with chemical N fertilizer replaced for 30% of N in M2 compost), P3 (70% of M3 compost combining with chemical N fertilizer replaced for 30% of N in M3 compost) and P4 (70% of M4 compost combining with chemical N fertilizer replaced for 30% of N in M4 compost). The applied compost in each treatment was based on the common application rate of compost in Vietnam of 25 tons ha^{-1} (equally 100%). Composts were applied at base ten days before transplanting. Chemical nitrogen fertilizer was applied at one day before transplanting. The leaf area index (LAI) and dry weight were measured at flowering stage and harvesting stage. LAI (m^2 of leaves m^{-2} of land) was determined according to the formula: LAI= ((A1× Number of plants/m^2 of land))/A2×100; A1 is the weight of whole fresh leaves of 1 plant (g), A2 is the weight of 1 dm^2 of fresh leaves (g). The shoots were cut 5 cm from the base and oven-dried at 80 °C until the weight is constant for determining dry weight. Average fruit weight was evaluated on 5 plants on each experimental plot. The actual yield was calculated as the total fruit weight of the harvests of each experimental plot. The process of growing and caring for cucumber was done according to organic farming. The experimental soil has not been cultivated organically before.

Statistical analysis

Analysis of variance was used to test for statistical differences in the chemical properties, biomass, germination parameters, cucumber fruit weight and yield among treatments, followed by Tukey's HSD test. The statistical analyses were performed using Statistix 8 (Analytical Software, Tallahassee, FL, USA).

RESULTS AND DISCUSSION

The components of composting piles

The compost pile volume was the same for all treatments (1 m^3). The composition of materials was adjusted so that the C/N ratio of the compost pile ranged from 25 to 30, which is the proper C/N proportion for composting process. Therefore, the weight of each type of compost material and the compost pile was different among treatments. For M1, the weight of straw was 33 kg, chicken manure was 15 kg and elephant grass was 60 kg. For M2, the weight of straw was 39 kg, chicken manure was 12 kg and cabbage leaf was 66 kg. For M3, the weight of straw was 21 kg, cow dung was 60 kg and elephant grass was 60 kg. For M4, the weight of straw was 36 kg, cow dung was 66 kg and cabbage leaf was 61 kg. Thus, the total weights of compost piles of M1, M2, M3, M4 were 108 kg, 117 kg, 141 kg, 163 kg, respectively (Table 2).

Effect of agricultural by-product as composting materials on physical-chemical properties of thermophilic compost

Temperature behavior of composting piles

The temperature of the compost piles with different combination of composting materials increased on the 2nd day after incubation. M2 reached 77 °C. M1 reached 68 °C. M4 reached 64 °C. M3 reached 50 °C. After the 1st and 2nd times of turning, the temperature of the compost piles still increased to around 70 °C (28/2). After the 3rd and 4th mixing, the temperature ranged from 50–60 °C. Thermophilic phases were happened on the 2nd day after composting and lasted about 21 days through composting period in all treatments. Then, cooling phase was observed with the temperature around 40 °C. Xiao et al. (2019) studied four composting methods and showed that the highest temperature was 60.1 °C. The study of Carl et al. (2019) with 4 composting material formulas (temperature measured weekly and composting piles were turned every 21 days) showed that thermophilic phases were happened in the second weeks with the temperature of the piles were above 55 °C. In the conducted experiment, balance in raw material ratio may resulted in the thermal phase appeared early and the pile temperature rose quickly. The reason of temperature rising would be the intense microbial activity which is resulted in degradation of organic matter by microorganism (Guene, 1995; Charnay, 2005). Hassen et al. (2001) reported that the organic matters are degraded by oxidation. This allows the energy contained in the chemical bonds of the substrate molecules to be released (Ryckeboer et al., 2003), resulting in temperature rising in the composting pile. Besides, in the conducted research, the materials of elephant grass and cabbage leaves had high water content. Therefore, when the pile temperature increased because of microbe activities, these materials decomposed and increased moisture in composting piles, creating anaerobic conditions while the surrounding material on the site of the pile was dry. After turning, the humidity was adjusted evenly (about 60%) and the temperature again increased according to the thermophilic composting process. After 30 days of composting, the temperature of the composting piles remained around 40 °C. Combining 3 types of raw material thus supported heat evolution and promoted rapid decomposition of materials. In the study of Slimani et al. (2023), the amount of poultry manure or cattle manure accounts for 50% of the total compost pile weight, and the composting time lasts up to 120 days. In the study of Carl et al. (2019), the ratio of materials of composting pile (v/v) is 1 rice straw: 1 food waste: 1 swine manure, and a composting period lasted 16 weeks. In the conducted research, although the amount of poultry manure or cow manure accounted for a small proportion of composting weight (Table 2), the temperature of composting pile increased according to the thermophilic composting process. This also indicates that adjusting the initial C/N ratio of composting piles in the range of 25–30 is appropriate for thermophilic composting (Table 2).

There were differences in temperature fluctuations between treatments using chicken manure (M1, M2) and treatments using cow manure (M3, M4). Specifically, the temperature of the compost piles using chicken manure increased rapidly after composting or turning. These compost piles also reached high temperatures of over 70 °C. Meanwhile, the temperature of compost piles using cow manure increased slower. This may be because the OM and C/N of cow manure were higher than that of chicken manure. The OM (%) of cow manure was highest at 86.70%, followed by straw, elephant grass, chicken manure and cabbage leaf (86.20%, 85.9%, 78.30%, 77.40%, respectively). The OC of cow manure was the highest at 48.17%, followed by straw at 47.89%, elephant grass at 47.72%, chicken manure at 43.50% and cabbage leaf reached 43.00%. The C/N ratio of straw was the highest at 58.40, followed by cow manure at 24.58, elephant grass at 21.21, chicken manure at 16.29 and cabbage leaf at 13.40% (Table 1). Low degradation rate under high C/N ratios causes slower growth and activity of aerobic microbes, resulting in longer time of raising composting pile temperature (Azim et al., 2018). Thus, mixing chicken manure and elephant grass or cabbage leaves as compost materials will be efficient for maintaining the temperature of the composting pile. Xiao et al. (2019) reported that the temperature of composting pile changed to a stable condition was about 39 days after composting. In the conducted study, it was about 22 days. The reason the incubation time in Xiao experiment was longer may be because the composting material was composed of a large proportion of fresh daily manure, initial amounts of the materials were 75 kg of fresh daily manure and 15 kg of rice straw. In the research of Carl et al. (2019), the pile of treatment AD2 (volume ratio of 1 rice straw: 1 food waste: 1 swine manure) reached nearly 70 °C temperature after 1 week of composting and the composting period lasted up to 16 weeks.

Chemical properties of compost

It can be seen that treatments with different composting materials had different effects on the physico-chemical properties of the composts (Table 3). Compost pH ranged from 7.6 (M4) to 8.1 (M1) which are suitably utilized for crop production. The OC and OM of M1 are the highest (70.4% and 39.1%), followed by those of M3 (69.0% and 38.3%), M2 (68.4% and 38.0%) and M4 (37.1% and 66.7%). Compost TP was highest in M2 (1.5%), following by in M1 (1.20%), M3 (0.92%) and M4 (0.79%). Compost TK was highest in M2 (4.06%) and M1 (4.02%), following by in M3 (3.34%) and M4 (3.24%). Compost TN was highest in M2 (2.93%), following by in M1 (2.76%), M3 (2.64%) and M4 (2.64%). The higher TN in the treatments containing chicken manure and cabbage leaves may be because they contained higher TN than other materials. Cabbage leaves had the highest total nitrogen content at 3.21%, followed by chicken manure at 2.67%, elephant grass at 2.25%, cow manure at 1.96% and straw at 0.82% (Table 1). The results in Table 3 also show that the treatments of M1 and M2 had better compost quality than the treatments of M3 and M4. Thus, composting of multiple components of agricultural wastes produced higher nutritional content compost compared to the initial composting materials after 45 days, especially using chicken manure and cabbage leaves. In the study by Carl et al. (2019), the nutrient contents of TN, TP, TK in AD2 treatment (1 rice straw: 1 food waste: 1 swine manure, ratio by volume) at 3rd week composting were 0.62%, 0.29% and 0.15% respectively. In the study of Xiao Yang et al. (2019), four composting methods were tested (material ratio were combination of 75 kg of fresh dairy manure: 15 kg of rice straw and volume of cylinder 1.27 m^3). The total nitrogen contents at 40 days after composting in the AC, MC, AnC and FC were 0.028%, 0.026%, 0.026%, 0.025%, respectively (AC, the compost pile was ventilated, turned every 5 days and covered with plastic film; MC, the compost pile was turned every 5 days and covered by plastic film; AnC, the compost pile was covered with plastic film; FC, the compost pile was not turned or ventilated or covered with plastic film).

Table 3. Chemical properties of compost

Chemical properties	Treatments				P value	*CV%*
	M1	M2	M3	M4		
pH	8.1	7.8	7.9	7.6	*<0.05*	1.98
OC (%)	39.1	38.0	38.3	37.1	*<0.05*	1.03
OM (%)	70.4	68.4	69.0	66.7	*<0.05*	1.33
TN (%)	2.76	2.93	2.64	2.64	*<0.05*	1.53
TP (%)	1.20	1.50	0.92	0.79	*<0.05*	4.92
TK (%)	4.02	4.06	3.34	3.24	*<0.05*	1.55
C/N	14.2	13.0	14.5	14.0	*<0.05*	2.93

The weight of matured compost

Table 4 shows that different compost materials clearly affected the biomass reduction rate of the compost piles. The treatment using chicken manure had a lower biomass reduction rate than the treatment using cow manure. Specifically, M2 showed the lowest biomass reduction rate (16.3%), followed by M1 (16.7%), M3 (31.9%) and M4 (37.2%). In the treatments using chicken manure, there was no difference in biomass reduction rate between treatments using elephant grass or cabbage leaves. However, in the treatments using cow manure, the rate of biomass reduction was lower in the treatment using elephant grass than in the treatment using cabbage leaves. Thus, in different composting material mixing treatments, using a combination of straw, chicken manure with elephant grass or cabbage leaves will yield a greater amount of matured compost.

Phytotoxicity of the matured composts

The compost maturity and phytotoxicity have been commonly evaluated by using germination index through doing germination test (Roe et al., 1997; Pascual et al., 1997; Tiqua and Tam, 1998; Selim et al., 2012; Pampuro et al., 2017; Carl et al., 2019; Xiao et al., 2019; Aylaj and Adani, 2023). Compost will be assumed as phytotoxic free when germination index is greater than 80% (Zucconi, 1981; Siles-Castellano et al., 2020). In the conducted study, the GI of the treatments reached 103.50% (M3), 112.43 (%), 114.24 % (M4), and 119.64% (M1). Thus, all composts were considered non-phytotoxic after 45 days of composting, evenly may generate a phytostimulant effect on seed germination (Siles-Castellano et al., 2020). In the study of Aylaj and Adani (2023), the time for GI to reach over 80% was 180 days of incubation for compost mixing separated municipal solid wastes and poultry manure at the ratio of 3:2 ww^{-1} (C1) and 252 days of incubation for mixture at the ratio of 2:3 ww^{-1} (C2) in tomato germination test. This time was much longer than in the conducted experiment, the reason could be due to the larger proportion of chicken manure used in the composting pile or high phytotoxicity in separated municipal solid wastes.

The effect of compost extract and distilled water (d.H_2O) on seed germination of *Spinacia oleracea* L. presented in Table 5 shows that the germination rate ranged from 83.33% (M3) to 90% (M1); root length ranged from 3.49 cm (d.H_2O) to 4.20 cm (M1); shoot length ranged from 4.45 cm (d.H_2O) to 5.05 cm (M2). Therefore, M1 and M2 treatments gave the better growth of Spinach seedlings than others. The effect of compost extract and deionized water on seed germination of *Brassica juncea* (L.) Czern. showed that the germination rate ranged from 86.67% (M3) to 93.33% (M4); root length ranged from 3.70 cm (d.H_2O) to 4.45 cm (M1); shoot length ranged from 4.85 cm (d.H_2O) to 5.38 cm (M1). Therefore, the M1 and M2 treatments also gave the better growth of Brassica seedlings than others. Thus, all of composts using different materials in this study had a positive effect on the germination rate and growth of Spinach and Brassica seedlings, in which treatments using straw, chicken manure with elephant grass or cabbage leaves gave higher results than the remaining treatments. Slimani et al. (2023) reported that using the compost containing poultry manure gave a higher wheat germination rate than using the compost containing cattle manure, while using the compost with cattle manure gave a higher tomato germination rate than when using the compost with poultry manure.

Effect of different compost types on the growth and yield of cucumber

The growth and yield of cucumber plants fertilized with composts of different composting materials are shown in Table 6. The results showed that different composts had statistically significant effects on LAI, dry weight, average fresh fruit weight and yield of cucumber. There were no significant differences of LAI and dry weight among treatments at flowering stage.

Table 4. Effect of agricultural by-product materials on the weight of matured compost

Parameter	Treatments				P value	CV%
	M1	M2	M3	M4		
Initial weight (kg)	108	98	141	148	-	-
Compost weight at 45 days composting (kg)	90	82	96	93.3	-	-
Biomass reduction rate (%)	16.7	16.3	31.9	37.2	*<0.05*	4.12

Table 5. Effect of compost extract and deionized water on seed germination

Treatments	Germination rate (%)	Root length (cm)	Shoot length (cm)	Germination index (%)
Spinacia oleracea L.				
M1	90.00	4.20^{a}	5.47^{a}	119.64^{a}
M2	86.67	4.12^{a}	5.05^{b}	114.24^{a}
M3	83.33	3.90^{ab}	4.61^{c}	103.50^{b}
M4	86.67	3.84^{ab}	4.74^{bc}	112.43^{ab}
d.H_2O	86.67	3.49^{b}	4.45^{c}	-
P value	-	<0.05	<0.05	<0.05
CV%	-	3.97	2.29	2.82
Brassica juncea (L.) Czern				
M1	90.00	4.45^{a}	5.38^{a}	125.15^{a}
M2	90.00	4.23^{a}	5.08^{ab}	117.82^{ab}
M3	86.67	3.98^{ab}	4.94^{ab}	105.72^{c}
M4	93.33	4.02^{ab}	4.93^{ab}	111.78^{bc}
d.H_2O	90.00	3.70^{b}	4.85^{b}	-
P value	-	<0.05	<0.05	<0.05
CV%	-	4.17	3.58	2.76

Note: *means followed by the same letter in each column are not significantly different in the LSD tests.

Table 6. Effect of compost types on the growth and yield of cucumber

Treatments	LAI (m^2 of leaves m^{-2} of land)		Dry matter (g plant^{-1})		Average fruit weight (g fruit^{-1})	Fruit yield (ton ha^{-1})
	Flowering stage	Harvesting stage	Flowering stage	Harvesting stage		
P1	1.58^{a}	1.70^{ab}	8.60^{a}	11.13^{a}	108.13^{ab}	17.66^{ab}
P2	1.59^{a}	1.71^{a}	8.90^{a}	11.17^{a}	113.00^{a}	18.83^{a}
P3	1.49^{a}	1.61^{b}	8.53^{a}	9.19^{b}	98.17^{c}	15.93^{b}
P4	1.55^{a}	1.65^{ab}	8.85^{a}	9.67^{b}	102.77^{bc}	16.36^{ab}
P value	>0.05	<0.05	>0.05	<0.05	<0.05	<0.05
CV%	3.31	2.02	2.17	4.18	2.05	5.75

Note: *means followed by the same letter in each column are not significantly different in the LSD tests.

However, at harvesting stage, significant differences of LAI and dry weight among treatments were found. The P2 treatment (1.71 m^2 of leaves m^{-2} of land) gave a statistically significant higher LAI than the P3 treatment (1.61 m^2 of leaves m^{-2} of land). The P2 (11.17 g plant^{-1}) and P1 (11.13 g plant^{-1}) treatments gave statistically significant higher dry weight than P4 (9.67 g plant^{-1}) and P3 (9.19 g plant^{-1}). The average fresh fruit weight was highest in P2 treatment (113.00 g fruit^{-1}), followed by P1 (108.13 g fruit^{-1}), P4 (102.77 g fruit^{-1}) and P3 (98.17 g fruit^{-1}). Therein, the P1 and P2 treatments gave the significantly higher fresh fruit weight compared with the P3 and P4 treatments. There were no significant differences in fresh fruit weight between treatments P1 and P2 or between P3 and P4. The yield of cucumber was highest in P2 treatment (18.83 tons ha^{-1}), followed by P1 (17.66 tons ha^{-1}), P4 (16.36 tons ha^{-1}) and P3 (15.93 tons ha^{-1}). In addition, there were no significant differences in cucumber yield among P1, P2 and P4 treatments. However, the P2 treatment gave the significant difference in yield compared with the P3 treatment. In short, the growth and yield of cucumbers in treatments of P1 and P2 were higher than those in the P3 and P4 treatments, this possibly is due to the higher nutritional content of the M1 and M2 composts compared to the M3 and M4 composts (Table 3). The highest C/N of the M3 compost could be the reason for the lowest yield of cucumber in the P3 treatment. Some studies showed that applying the compost made from multiple agricultural production residues or combination of this compost with chemical fertilizer had a positive effect on agricultural crops. Anita et al. (2024) reported that using the compost with variety of composting materials (sewage sludge, sawdust, garden and part waste) improved the growth and yield of corn in comparison with control of no use compost. Applying poultry manure, or combining poultry manure with chemical fertilizer had a better effect on growth and yield of tomato compared to using chemical fertilizers (Tonfack et al., 2009). Sujatha et al. (2023) showed that replacing or mixing peat with biochar-compost improved the growth and yield of potted cucumber comparing with control. The growth and yield of lettuce were increased when applying of 10% BA food waste compost in pot experiment (Aunkamol et al., 2022). Eifediyi and Remison (2010) reported that increasing the farmyard manure from 0 to 5 or 10 tons ha^{-1} significantly increased the cucumber yield in Nigeria. The obtained experiment results showed that the composts made from rice straw, chicken manure and elephant grass or cabbage leaves gave better effect on the growth and yield of cucumber.

CONCLUSIONS

Multi-component composting using agricultural by-products such as rice straw, chicken manure, cow manure, elephant grass and cabbage leaves produced organic compost that is rich in nutrients and good for plants. The combination of different composting materials resulted in different effects on the thermos fluctuation of composting piles, the quality and volume of matured compost. The composting treatments using rice straw, chicken manure with elephant grass or cabbage leaves gave better temperature changes, higher compost quality and more compost volume than others. These combinations also had good effects on germination rate, root length, shoot length, germination index of Brassica and Spinach seed. Among fertilizer applications, applying 70% compost of M1 (rice straw, elephant grass, chicken manure) or M2 (rice straw, cabbage leaves, chicken manure) combined with chemical N fertilizer replacing 30% of N in compost applied to soil significantly increased the fresh fruit weight and yield of cucumber. The agricultural by-products thus should be converted into nutritious compost which is healthy food feeding soil and crops to contribute to closing the food chain in circular agriculture, protecting environment, and developing agriculture production sustainably.

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