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Effect of composted plant based and animal derived materials on Chinese kale (*Brassica oleracea* var. *alboglabra)* performance in raised beds

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Abstract The application of organic planting materials influenced the physicochemical properties of growing media and significantly affected the growth and yield of Chinese kale cultivated in raised beds. Composted animal manures, particularly porcine and poultry manure, provided higher nitrogen and phosphorus levels, enhancing vegetative growth. Among the plant-based materials, rain tree leaves contained the highest nitrogen content; however, high nitrogen alone did not guarantee optimal growth, emphasizing the importance of nutrient balance and physical media structure. Rice husk biochar improved porosity, bulk density, and water-holding capacity, yet failed to achieve the highest yield when applied alone. The combination of filter cake or old mushroom lumps with porcine manure led to superior plant height, stem diameter, canopy width, leaf number, and leaf size. These treatments also showed higher leaf greenness, highest fresh and dry biomass, and lower root-to-shoot ratios, reflecting efficient biomass allocation toward harvestable parts. Although plant-based and animal-based materials showed significant individual effects, their interaction was not statistically significant, suggesting additive rather than synergistic effects. The superior performance of magnesium-rich materials such as filter cake highlighted the role of magnesium in chlorophyll synthesis and leaf development. Overall, integrating nutrient-dense animal manures with structurally beneficial plant-based materials improved the fertility and physical quality of growing media, resulting in enhanced growth and yield of Chinese kale. These findings demonstrated the potential of locally available organic resources, particularly combinations of porcine manure with filter cake or mushroom waste, as viable alternatives to chemical fertilizers for sustainable leafy vegetable production in raised bed systems.

Keywords: Planting materials, Animal manures, Organic vegetable, Raised bed systems

Introduction

The increasing demand for high-yield agricultural production has led to the extensive use of chemical inputs, particularly synthetic fertilizers and pesticides. While these inputs contribute to immediate productivity gains, they

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also result in long-term environmental degradation and serious health risks for consumers. In Thailand, chemical contamination in fruits and vegetables is a persistent concern. According to the Thailand Pesticide Alert Network, 58.7% of tested fruits and vegetables contained pesticide residues exceeding safety standards (Thailand Pesticide Alert Network, 2020). Disturbingly, 100% of samples from popular vegetables including small tomatoes, bird's eye chilies, celery, and Chinese kale tested positive for unsafe levels of pesticide contamination (Bangkokbiznews, 2020). These findings have heightened public concern and spurred increased interest in organic agriculture as a safer and more sustainable alternative.

Chinese kale (*Brassica oleracea* var. *alboglabra*) is a leafy vegetable in the Cruciferae family that is widely cultivated and consumed in Thailand. It can be grown year-round, making it an economically valuable crop for both smallholder and commercial farmers. In 2019, the planting area of Chinese kale across 69 provinces totaled 47,328 rais, producing 45,162 tons of yield (Information and Communication Technology Center, 2019). However, like many leafy vegetables, Chinese kale is often grown using conventional chemical-intensive methods that raise concerns about food safety. To address this, organic vegetable farming has emerged as an alternative that supports environmental sustainability while ensuring consumer safety and health. Organic vegetable production, however, presents its own set of challenges. Key among them is the preparation of effective planting media that not only supports plant growth but also aligns with organic farming principles. Unlike conventional systems that rely on synthetic inputs, organic farming depends heavily on the use of natural resources, particularly organic residues, to improve soil fertility and physical conditions. These planting materials must meet several criteria: they should supply essential nutrients, maintain moisture retention, ensure adequate aeration, support root development, and facilitate good drainage. Furthermore, organic materials often require composting or fermentation to enhance their usability and safety before application in the field (Lukrak and Athinuwat, 2013). Each region has access to different types of agricultural waste and organic residues that can potentially be reused for soil improvement.

In Uttaradit Province, a region with extensive agricultural activity, 25.51% of the total land area is used for farming. The agricultural landscape includes rice fields (681,400 rai), field crops (315,808 rai), and perennial plantations (153,646 rai), in addition to livestock and aquaculture zones (Uttaradit Provincial Agriculture and Cooperative Office, 2022). Alongside farming, local agro-industrial operations such as sugar production from sugarcane, distillation of alcoholic beverages, and rice milling generate large quantities of organic by-products. These include rice straw, rice husks, filter cake, spent mushroom substrate, and brewing residues, which are often underutilized or improperly disposed.

Recent attention has turned to these local resources as viable components for preparing organic planting materials. When properly composted or combined with nutrient-rich additives such as animal manures, these organic residues can enhance soil structure, improve nutrient availability, and support crop productivity. Examples include rice husk charcoal or biochar, which improves aeration and water holding capacity; filter cake, which provides magnesium and organic matter; and vermicompost, known for its balanced nutrient composition (Edwards, 2004; Inthasan *et al.,* 2023; Srisaikham and Rupitak, 2023). However, while these materials are widely available, there is limited scientific research comparing their relative effectiveness as planting substrates particularly in combination with animal-derived inputs such as manure.

In parallel with the use of organic residues, raised bed cultivation has gained popularity as a production technique for organic vegetables. Raised beds improve soil drainage, reduce soil compaction, and facilitate easier weeding and harvesting. They have also been shown to reduce water use and lower weed pressure significantly. Miernicki *et al.* (2018) reported that raised bed systems decreased irrigation demand by 32% and reduced grass and broadleaf weed abundance by 93–97%. Moreover, raised beds have been associated with higher yields for vegetables such as radish, kale, and cilantro, regardless of the type of growing media used. The raised structure helps avoid waterlogging and improves root aeration, making it especially suitable for organic systems where soil-borne diseases can be problematic. Khwunsakun (2022) also found that vegetables grown in raised plots had significantly higher fresh weights, supporting the system's effectiveness. Despite the availability of organic resources and the benefits of raised bed cultivation, there remains a critical gap in understanding how combinations of different plant-based and animal-derived materials affect plant growth, especially in small scale organic systems. While individual materials like rice husk biochar or porcine manure have shown potential, their combined effects and how they influence plant growth dynamics, soil properties, and yield require systematic investigation. Moreover, the chemical and physical characteristics of these materials can vary significantly depending on their origin and composition, which may affect their suitability for use as growing media.

Therefore, this study aimed to evaluate the effects of different organic planting materials comprising locally available plant-based residues and animal manures on the physicochemical properties of growing media and the subsequent growth and yield of Chinese kale cultivated in raised beds.

Materials and methods

The experiment was conducted at the plant nursery of the Faculty of Agriculture, Uttaradit Rajabhat University, Thailand, from May to July 2023. The objective was to evaluate the effects of different plant-based organic materials and animal manures as components of growing media on the growth and yield of organic Chinese kale. The experimental was performed as 2 factors factorial experiment in Completely Randomized Design (CRD) with three replications. The two factors were as follows:- Factor A type of plant-based organic matter (6 types), consisting of copper pod leaves (*Peltophorum pterocarpum* (DC.)), dried rice straw, rice husk biochar, rain tree leaves (*Samanea saman* (Jacq.) Merr.), old mushroom lumps, and filter cake (a sugarcane processing byproduct). These materials were mixed with soil at a 1:3 ratio (soil:organic matter). Factor B type of animal manure (3 types), including cow manure, chicken manure, and porcine (pig) manure. All organic materials were air-dried, chopped or ground as needed, and combined according to treatment combinations at a ratio of 1:2:3 (soil: organic matter: animal manure). The mixtures were composted for 60 days before use. The chemical and physical properties of each treatment mixture were analyzed. Chemical properties included pH, electrical conductivity (EC), organic matter content (OM), and concentrations of essential nutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Physical properties assessed were bulk density, water-holding capacity, total porosity, and air porosity. Chinese kale seedlings were initially grown in seedling trays for 14 days and then transplanted into 20-liter plastic containers filled with the respective growing media. Each container held three plants, with three replications per treatment. The containers were placed on bench shelves raised 80 cm above ground level to facilitate drainage and minimize soil-borne interference. All containers were arranged randomly in the nursery and managed under standard organic cultivation practices. No synthetic fertilizers or pesticides were applied, and weed control was performed manually. Irrigation was provided via micro-sprinklers. Growth and yield data were recorded 30 days after transplanting. Growth parameters measured included plant height, stem diameter, canopy width, number of leaves, leaf length and width, leaf greenness, and leaf area. Yield parameters included fresh and dry weight per plant. All data were subjected to analysis of variance (ANOVA) using IBM SPSS Statistics version 26. When significant differences were detected, means were compared using Duncan's New Multiple Range Test (DMRT) at a significance level of $p \leq 0.05$.

Results

The chemical properties of composted planting materials

After 60 days of fermentation, the composted planting materials—derived from various plant-based residues mixed with different types of animal manures showed significant variation in their chemical properties. The pH values across all treatments ranged from 6.55 to 7.90. The lowest pH was observed in the treatment with rain tree leaves + porcine manure (6.55), while the highest was in old mushroom lumps + poultry manure (7.90). All treatments-maintained pH values within the acceptable range for Chinese kale cultivation (6.0–7.5). Electrical conductivity (EC) varied markedly among treatments, ranging from 0.88 to 3.63 mS/cm. The highest EC value (3.63 mS/cm) was found in the dried rice straw + poultry manure treatment, while the lowest (0.88 mS/cm) occurred in rice husk biochar + cattle manure. Organic matter (OM) content ranged from 11.50% to 23.44%. The highest OM was recorded in old mushroom lumps + poultry manure (23.44%), while the lowest was in rice husk biochar + porcine manure (11.50%). About plant nutrients, total nitrogen (N) content exceeded 1.0% in several treatments, with the highest value (1.05%) recorded in dried rice straw + poultry manure. Treatments involving poultry and porcine manure generally exhibited higher N content than those with cattle manure. Phosphorus (P) ranged from 0.13% to 1.87%. The highest P concentration was observed in dried rice straw + porcine manure (1.87%), followed by dried rice straw + poultry manure (1.60%). Treatments containing cattle manure consistently had lower P concentrations. Potassium (K) values ranged from 0.43% to 1.09%, with the highest in dried rice straw + cattle manure. Treatments with porcine and poultry manure exhibited moderate K values, notably 1.00% in filter cake + porcine manure. Calcium (Ca) content displayed the most substantial variation, ranging from 0.12% to 2.59%. Treatments with poultry manure, especially dried rice straw + poultry manure, yielded the highest Ca content (2.59%). Cattle manure-based treatments generally showed the lowest Ca values. Magnesium (Mg) ranged from 0.25% to 0.68%. The highest Mg content was recorded in dried rice straw + poultry manure (0.68%), followed by copper pod leaves + poultry manure (0.54%) and filter cake + porcine manure (0.55%). In summary, composted planting materials combining plant-based residues with poultry or porcine manures tended to exhibit higher levels of essential nutrients (N, P, Ca, Mg), while rice husk biochar showed lower nutrient values but maintained favorable OM and pH. These results provide a quantitative basis for selecting suitable substrate mixtures for Chinese kale cultivation (Table 1).

Table 1. Chemical properties of planting materials mixed with different animal manures after 60 days of fermentation

Treatments	pH	EC (mS/cm)	OM (%)	Total N (%)	P (%)	K (%)	Ca (%)	Mg (%)
1. copper pod leaves + cattle manure	7.48	0.98	20.15	0.61	0.19	0.84	0.47	0.45
2. dried rice straw + cattle manure	7.80	1.00	11.90	0.47	0.13	1.09	0.18	0.53
3. rice husk biochar + cattle manure	7.53	0.88	13.70	0.38	0.16	0.47	0.12	0.25
4. rain tree leaves + cattle manure	7.58	0.89	14.23	0.53	0.13	0.87	0.26	0.48
5. old mushroom lumps + cattle manure	7.88	0.98	19.65	0.68	0.15	0.58	0.51	0.40
6. filter cake + cattle manure	7.42	1.01	18.42	0.85	0.74	0.82	0.61	0.42
7. copper pod leaves + poultry manure	7.65	1.80	21.11	1.01	1.44	0.60	2.46	0.54
8. dried rice straw + poultry manure	7.72	3.63	17.86	1.05	1.60	0.91	2.59	0.68
9. rice husk biochar + poultry manure	7.48	0.98	20.15	0.61	0.19	0.46	1.44	0.31
10. rain tree leaves + poultry manure	7.80	1.00	11.90	0.47	0.13	0.60	2.15	0.49
11. old mushroom lumps + poultry manure	7.90	2.31	23.44	0.97	1.33	0.82	2.41	0.58
12. filter cake + poultry manure	6.59	1.70	22.24	0.84	0.71	0.61	0.86	0.45
13. copper pod leaves + porcine manure	7.40	1.92	18.92	1.00	1.50	0.86	1.79	0.52
14. dried rice straw + porcine manure	6.60	1.94	19.78	0.82	1.87	0.62	1.64	0.54
15. rice husk biochar + porcine manure	6.76	1.07	11.50	0.32	0.94	0.43	0.56	0.30
16. rain tree leaves + porcine manure	6.55	1.17	14.30	0.84	0.69	0.49	0.66	0.34
17. old mushroom lumps + porcine manure	7.38	1.32	23.14	0.86	0.73	0.68	1.04	0.46
18. filter cake + porcine manure	6.67	2.16	19.35	0.92	1.28	1.00	1.15	0.55

The physical properties of composted planting materials

The physical properties of composted planting materials those derived from various combinations of plant-based organic matter and animal manures, after 60 days of fermentation. The bulk density of the plant residues (Factor A) ranged from 1.57 to 1.70 g/cm³. According to the F-test, plant material type had a statistically significant effect on bulk density ($p < 0.01$). Dried rice straw recorded the highest bulk density (1.70 ± 0.14 g/cm³), whereas copper pod leaves and old mushroom lumps had the lowest (1.57 ± 0.06 g/cm³). Total porosity varied from 43.86% to 61.50% among plant materials. The highest porosity was observed in rice husk biochar (61.50 ± 13.50%), while rain tree leaves exhibited the lowest (43.86 ± 11.63%). However, the differences in total porosity between plant materials were not statistically significant. Water-holding capacity (WHC) of the plant residues ranged from 41.54% to 56.24%. Rice husk biochar had the highest WHC (56.24 ± 8.54%), followed by old mushroom lumps (44.91 ± 11.92%). The effect of plant material on WHC was statistically significant ($p < 0.05$). Air porosity values ranged from 2.19% to 5.26%, with rice husk biochar exhibiting the highest value (5.26 ± 5.35%). No significant difference was found among treatments in this parameter. For the animal manures (Factor B), bulk density ranged from 1.57 to 1.66 g/cm^3. Cattle manure had the highest value (1.66 ± 0.14 g/cm^3), and poultry manure the lowest (1.57 ± 0.08 g/cm^3). The F-test indicated that the manure type significantly influenced bulk density ($p < 0.01$). There were no statistically significant differences among manure types in terms of total porosity, WHC, or air porosity. The combined treatments of plant residues and manures (A × B interaction) demonstrated bulk densities ranging from 1.48 to 1.88 g/cm^3. The highest value was observed in the dried rice straw + cattle manure mixture (1.88 ± 0.01 g/cm^3), and the lowest in filter cake + poultry manure (1.48 ± 0.03 g/cm^3). The interaction effect on bulk density was statistically significant ($p < 0.05$). Total porosity ranged from 36.53% to 65.71%, with rice husk biochar + porcine manure showing the highest value (65.71 ± 18.05%). Water-holding capacity also peaked in this treatment (59.15 ± 9.61%). Air porosity ranged widely across combinations, with values between 1.66% and 6.56%. However, interaction effects for total porosity, WHC, and air porosity were not statistically significant (Table 2).

Effects of organic planting materials and animal manure on stem growth of Chinese kale in raised bed system

The results show that plant material type (Factor A) significantly influenced plant height, stem diameter, and canopy width ($p < 0.05$), while animal manure type (Factor B) significantly affected all measured stem growth parameters ($p < 0.05$). However, no significant interaction effects between plant materials and animal manures were observed. Among the plant materials tested, rice husk biochar, rain tree leaves, old mushroom lumps, and filter cake significantly increased plant height compared to copper pod leaves and dried rice straw, with rice husk biochar yielding the tallest plants (24.99 ± 6.78 cm). Stem diameter was largest when Chinese kale was grown in substrates containing old mushroom lumps and filter cake (12.90 ± 1.38 mm and 13.12 ± 2.58 mm, respectively). Filter cake also promoted the widest canopy (42.32 ± 7.91 cm), which can indicate better vegetative growth and light interception. Regarding animal manures, porcine manure consistently resulted in the greatest stem height (24.54 ± 5.99 cm), stem diameter (13.14 ± 2.19 mm), and canopy width (41.06 ± 7.55 cm), while cattle and poultry manures showed comparatively lower growth values (Table 3).

Table 2. Physical properties of fermented organic planting materials and animal manure combinations for Chinese kale cultivation

Factor		bulk density[1] (g/cm^3)	total porosity (%)	water-holding capacity[1] (%)	air porosity (%)
A Plant-base organic matters	copper pod leaves	1.57±0.06^{b}	44.64±11.85	41.75±10.06^{b}	2.89±2.07
	dried rice straw	1.70±0.14^{a}	44.85±12.39	42.15±11.15^{b}	2.70±1.56
	rice husk biochar	1.63±0.12^{ab}	61.50±13.50	56.24±8.54^{a}	5.26±5.35
	rain tree leaves	1.59±0.11^{b}	43.86±11.63	41.54±9.88^{b}	2.32±1.83
	old mushroom lumps	1.57±0.06^{b}	47.10±13.67	44.91±11.92^{b}	2.19±2.19
	filter cake	1.60±0.11^{b}	45.64±11.55	42.67±8.82^{b}	2.97±3.00
B Animal manures	cattle manure	1.66±0.14^{a}	43.57±14.00	41.21±12.43	2.36±1.87
	poultry manure	1.57±0.08^{b}	50.28±12.07	46.95±9.59	3.33±2.91
	porcine manure	1.61±0.08^{ab}	49.94±13.66	46.47±10.38	3.47±3.91
A x B	copper pod leaves + cattle manure	1.52±0.00^{bc}	40.75±15.58	38.21±13.49	2.53±2.10
	dried rice straw + cattle manure	1.88±0.01^{a}	36.53±17.09	34.64±16.09	1.89±1.01
	rice husk biochar + cattle manure	1.61±0.15^{bc}	54.42±11.28	50.58±8.62	3.84±2.74
	rain tree leaves + cattle manure	1.68±0.10^{b}	42.20±14.89	40.18±13.13	2.01±1.80
	old mushroom lumps + cattle manure	1.60±0.05^{bc}	44.32±17.81	42.66±16.82	1.66±1.01
	filter cake + cattle manure	1.67±0.14^{b}	43.20±14.05	40.96±11.34	2.24±2.84
	copper pod leaves + poultry manure	1.60±0.08^{bc}	43.83±10.43	41.24±9.03	2.59±1.69
	dried rice straw + poultry manure	1.61±0.03^{bc}	50.68±9.98	47.37±7.68	3.31±2.53
	rice husk biochar + poultry manure	1.64±0.11^{bc}	64.36±12.69	58.99±7.26	5.37±5.46
	rain tree leaves + poultry manure	1.54±0.08^{bc}	45.89±12.22	42.90±9.83	3.00±2.39
	old mushroom lumps + poultry manure	1.53±0.05^{bc}	52.33±13.37	49.33±9.75	3.00±3.63
	filter cake + poultry manure	1.48±0.03^{c}	44.60±9.81	41.88±7.65	2.72±2.41
	copper pod leaves + porcine manure	1.60±0.04^{bc}	49.34±12.40	45.81±9.89	3.53±2.99
	dried rice straw + porcine manure	1.62±0.04^{bc}	47.33±7.64	44.44±6.78	2.89±0.87
	rice husk biochar + porcine manure	1.66±0.14^{b}	65.71±18.05	59.15±9.61	6.56±8.45
	rain tree leaves + porcine manure	1.54±0.12^{bc}	43.50±12.61	41.54±10.75	1.96±1.86
	old Mushroom Lumps + porcine manure	1.57±0.07^{bc}	44.65±13.78	42.73±12.11	1.92±1.86
	filter cake + porcine manure	1.64±0.03^{bc}	49.12±14.52	45.16±10.47	3.97±4.44
F-test	A	**	ns	*	ns
	B	**	ns	ns	ns
	A x B	*	ns	ns	ns
C.V.(%)		5.22	28.21	24.36	108.22

1/ Data in the table were average ± standard error (n=3), and different letters for the same cultivar indicated a significant difference at a 5 % level (DMRT).

Table 3. effects of organic planting materials and animal manure on stem growth of Chinese kale in raised bed system

Factor		height[1] (cm)	stem diameter[1] (mm)	canopy width[1] (cm)
A plant-base organic matters	copper pod leaves	18.41±3.52^{b}	11.03±3.80^{ab}	33.49±10.01^{b}
	dried rice straw	18.38±4.03^{b}	9.50±4.06^{b}	26.46±9.26^{c}
	rice husk biochar	24.99±6.78^{a}	10.90±2.44^{ab}	36.90±10.20^{ab}
	rain tree leaves	22.97±3.85^{a}	10.41±3.27^{ab}	34.49±8.31^{b}
	old mushroom lumps	23.22±4.91^{a}	12.90±1.38^{a}	38.46±6.65^{ab}
	filter cake	22.62±2.37^{a}	13.12±2.58^{a}	42.32±7.91^{a}
B animal manures	cattle manure	18.94±3.519^{c}	9.64±3.52^{b}	31.89±11.23^{b}
	poultry manure	21.81±3.26^{b}	11.15±2.85^{b}	33.11±7.74^{b}
	porcine manure	24.54±5.99^{a}	13.14±2.19^{a}	41.06±7.55^{a}
F-test	A	**	*	**
	B	**	**	**
	A x B	ns	ns	ns
C.V.(%)		16.16	22.71	20.77

1/ Data in the table were average ± standard error (n=3), and different letters for the same cultivar indicated a significant difference at a 5 % level (DMRT).

Effects of organic planting materials and animal manure on leaf growth of Chinese kale in raised beds system

The effects of various plant-based organic materials and animal manures on leaf growth characteristics of Chinese kale cultivated using the raised bed system. The measured parameters include number of leaves per plant, leaf width, leaf length, leaf area, and leaf greenness (SPAD unit). The significant differences were observed among plant-based organic materials in terms of the number of leaves per plant ($p < 0.05$). The highest leaf number was recorded in the filter cake treatment (8.44 ± 1.51 leaves), which was statistically similar to old mushroom lumps (8.33 ± 1.22), but significantly higher than copper pod leaves (6.78 ± 1.64) and dried rice straw (6.67 ± 1.12). Leaf width and length were not significantly affected by Factor A. However, old mushroom lumps and filter cake resulted in higher average values for leaf width (11.68 ± 3.16 cm and 10.10 ± 2.25 cm, respectively) and leaf length (17.79 ± 3.90 cm and 14.81 ± 3.07 cm, respectively). Leaf area was highest with old mushroom lumps (141.61 ± 48.41 cm^2), followed by filter cake, although differences were not statistically significant. Leaf greenness was not significantly influenced by the type of plant-based organic material, with SPAD values ranging from 49.69 ± 4.00 (filter cake) to 54.88 ± 6.28 (rain tree leaves). The type of animal manure significantly affected number of leaves per plant ($p < 0.05$), leaf width ($p < 0.01$), leaf length ($p < 0.05$), leaf area ($p < 0.05$), and leaf greenness ($p < 0.01$). Porcine manure consistently promoted better vegetative growth across multiple parameters, resulting in the greatest leaf width (10.86 ± 2.84 cm), leaf length (15.88 ± 3.92 cm), and leaf area (145.16 ± 59.84 cm^2). It also led to the highest SPAD value (53.44 ± 5.20), indicating greater chlorophyll content. Cattle manure produced the lowest values in most parameters, particularly leaf area (104.91 ± 52.14 cm²) and SPAD value (53.11 ± 5.38), though the difference in SPAD compared to poultry manure (48.67 ± 4.21) was relatively minor. No significant interaction effects between plant-based materials and animal manures were detected for any parameter (Table 4).

Table 4. effects of different organic planting materials derived from plant residues and animal manures on leaf growth characteristics of Chinese kale grown using the raised bed system

	Factor	**number of leaf[1] (leaf/plant)**	**leaf width[1] (cm.)**	**leaf length[1] (cm)**	**leaf area[1] (cm^2)**	**leaf greenness (SPAD unit)[1]**
A Plant-base organic matters	copper pod leaves	6.78±1.64^{b}	9.59±3.37	14.53±5.23	127.8±77.84	51.64±6.01
	dried rice straw	6.67±1.12^{b}	8.90±3.48	12.97±5.50	96.47±47.42	50.84±6.14
	rice husk biochar	7.89±1.45^{ab}	9.74±2.17	14.46±3.70	119.35±29.13	52.16±5.95
	rain tree leaves	7.67±1.87^{ab}	8.56±1.87	13.07±3.64	106.28±55.85	54.88±6.28
	old mushroom lumps	8.33±1.22^{a}	11.68±3.16	17.79±3.90	141.61±48.41	51.21±2.61
	filter cake	8.44±1.51^{a}	10.10±2.25	14.81±3.07	130.55±40.65	49.69±4.00
B Animal manures	cattle manure	7.06±1.47^{b}	8.32±2.65^{b}	12.46±4.06^{b}	104.91±52.14^{b}	53.11±5.38^{a}
	poultry manure	7.56±1.42^{ab}	10.11±2.54^{a}	15.47±4.49^{a}	110.95±33.04^{b}	48.67±4.21^{b}
	porcine manure	8.28±1.67^{a}	10.86±2.84^{a}	15.88±3.92^{a}	145.16±59.84^{a}	53.44±5.20^{a}
F-test	A	*	ns	ns	ns	ns
	B	*	**	*	*	**
	A x B	ns	ns	ns	ns	ns
C.V.(%)		18.10	25.23	26.26	42.12	9.59

1/ Data in the table were average ± standard error (n=3), and different letters for the same cultivar indicated a significant difference at a 5 % level (DMRT).

Effects of organic planting materials and animal manure on yield of Chinese kale

The effects of different combinations of organic planting materials derived from plant residues and various animal manures on the fresh and dry weight yields of Chinese kale, including shoot and root biomass, as well as root-to-shoot ratios. The data show that plant material type (Factor A) significantly influenced fresh shoot weight, root-to-shoot ratio for fresh weight, dry shoot weight, and dry root-to-shoot ratio ($p < 0.05$). Filter cake as a planting material produced the highest fresh shoot weight (155.11 ± 64.67 g) and dry shoot weight (16.40 ± 6.82 g), indicating its potential to enhance biomass accumulation in Chinese kale. Copper pod leaves and old mushroom lumps also showed relatively high yields. Animal manure type (Factor B) had a highly significant effect ($p < 0.01$) on most yield parameters, including fresh and dry weights of shoots and roots, as well as root-to-shoot ratios. Porcine manure consistently resulted in the greatest fresh shoot weight (153.54 ± 57.3 g), dry shoot weight (16.44 ± 6.17 g), and generally lower root-to-shoot ratios, suggesting a greater allocation of biomass to shoots compared to roots. Cattle manure showed the lowest biomass production in all parameters. No significant interaction effects between plant materials and animal manure types were observed, indicating their independent contributions to yield (Table 5).

Table 5. effects of different combinations of organic planting materials derived from plant residues and various animal manures on the yields of Chinese kale

Factor		fresh weight (g)			dry weight (g)		
		shoots[1]	roots[1]	roots to shoots[1]	shoots[1]	roots[1]	roots to shoots[1]
A Plant-base organic matters	copper pod leaves	100.26±78.73^{b}	6.50±4.25	0.08±0.03^{a}	11.18±7.88^{abc}	1.41±0.76	0.15±0.05^{a}
	dried rice straw	73.09±57.29^{b}	4.67±3.62	0.07±0.01^{ab}	8.01±6.11^{c}	0.97±0.65	0.14±0.03^{ab}
	rice husk biochar	104.5±62.64^{ab}	6.03±3.02	0.06±0.02^{ab}	11.93±7.42^{abc}	1.31±0.64	0.12±0.03^{abc}
	rain tree leaves	92.25±59.26^{b}	5.29±2.84	0.06±0.02^{ab}	10.11±6.17^{bc}	1.15±0.57	0.12±0.03^{abc}
	old mushroom lumps	125.2±40.19^{ab}	6.18±1.48	0.05±0.02^{b}	14.09±3.62^{ab}	1.43±0.33	0.11±0.03^{bc}
	filter cake	155.11±64.67^{a}	7.32±2.81	0.05±0.01^{b}	16.40±6.82^{a}	1.61±0.68	0.10±0.03^{c}
B Animal manures	cattle manure	73.23±54.49^{b}	4.38±2.90^{b}	0.07±0.02^{a}	8.44±5.93^{b}	1.03±0.64^{b}	0.14±0.04^{a}
	poultry manure	98.44±54.87^{b}	5.86±2.51^{b}	0.06±0.02^{ab}	10.97±5.76^{b}	1.30±0.52^{ab}	0.13±0.03^{a}
	porcine manure	153.54±57.3^{a}	7.76±3.01^{a}	0.05±0.02^{c}	16.44±6.17^{a}	1.61±0.61^{a}	0.10±0.03^{b}
F-test	A	*	ns	*	*	ns	*
	B	**	**	*	**	**	**
	A x B	ns	ns	ns	ns	ns	ns
C.V.(%)		48.06	42.73	29.28	46.32	40.44	25.73

1/ Data in the table were average ± standard error (n=3), and different letters for the same cultivar indicated a significant difference at a 5 % level (DMRT).

Discussion

This study comprehensively evaluated the effects of different organic planting materials, derived from various plant residues and animal manures, on the physicochemical properties of growing media and subsequent growth and yield of Chinese kale cultivated in raised beds. The chemical properties of the composted planting materials revealed variations in pH, EC, OM, and key nutrients such as N, P, K, Ca, and Mg. Notably, treatments containing poultry and porcine manure exhibited higher nutrient concentrations, especially N and P, which are vital for vegetative development (Liu *et al.*, 2018; Zhang *et al.,* 2020). Among plant residues, rain tree leaves exhibited the highest nitrogen content, confirming previous work by Sangchote (2008), who reported improved soil nitrogen levels following decomposition of rain tree leaf litter. However, our findings showed that high nitrogen content alone did not always result in superior plant performance, suggesting that other factors such as nutrient balance, physical properties of the media, and nutrient release dynamics also play critical roles. Physical analysis of the planting materials showed that rice husk biochar-based media had the most favorable structure, characterized by low bulk density, high porosity, and enhanced water-holding capacity. These features support improved root development and nutrient uptake by maintaining aeration and moisture in the rhizosphere (Chen *et al.,* 2017; Lehmann and Joseph, 2015). Despite this advantage, biochar-based treatments alone did not lead to the highest growth or yield, underscoring the importance of combining physical improvements with adequate nutrient supply. In addition, Miernicki *et al*. (2018) who stated that raised beds should combine the soil material with compost and soil for vegetable production. Growth assessments revealed that planting materials combining filter cake or old mushroom lumps with porcine manure significantly enhanced plant height, stem diameter, canopy width, leaf size, and number of leaves per plant. These results indicate a synergistic effect of magnesium-rich residues like filter cake (Poonpakdee and Onthong, 2021) and nutrient-dense animal manures in promoting leaf development and photosynthetic capacity, which similarity reported to improve soil fertility and crop performance by Inthasan *et al.* (2023). This aligns with the work of Bhattacharyya *et al*. (2015), who reported that organic amendments improve leaf area and biomass in vegetable crops. Furthermore, increased leaf greenness (SPAD value) in these treatments suggests enhanced nitrogen assimilation and photosynthetic efficiency. Yield data confirmed the vegetative growth trends, with the highest fresh and dry weights observed in treatments using filter cake and porcine manure. These combinations also resulted in lower root-to-shoot ratios, reflecting an efficient allocation of biomass toward the harvestable shoots a trait highly desirable for leafy vegetable production. This agrees with Lesing and Anugoolprasert (2016), who found that nitrogen-rich organic fertilizers increased shoot biomass and leaf area in kale. Interestingly, while individual effects of plant and animal derived materials were significant, their interaction was not, indicating that their effects are additive rather than synergistic. This finding provides flexibility for growers to select inputs based on availability, environmental context, or cost-efficiency without concern for complex interactions (Lukrak and Athinuwat, 2013). Beyond nutrient availability, the physical properties of the media also contributed to plant growth. For instance, the porosity and water retention associated with biochar-based materials likely improved water use efficiency, especially under raised bed conditions, where rapid drainage can be a limitation (Miernicki *et al*., 2018).

In summary, this study offers practical insights for sustainable vegetable production, highlighting the effectiveness of integrating organic residues such as filter cake and mushroom lumps particularly when combined with porcine manure as viable alternatives to synthetic fertilizers. While amendments like rice husk biochar may lack nutrients, their beneficial impact on soil structure makes them valuable when strategically blended with nutrient-rich materials to optimize aeration, moisture retention, and fertility. Given the absence of significant interactions between plant and animal-based sources, farmers are encouraged to tailor input combinations based on locally available organic waste streams. Additionally, the prominent role of magnesium in enhancing plant growth and chlorophyll content underscores the importance of incorporating Mg-rich materials like filter cake in compost formulations. Overall, these findings support a transition to organic farming practices by demonstrating that composted residues can effectively sustain growth and yield, reducing the reliance on chemical fertilizers (Edwards, 2004; Vanaprasert *et al*., 2013). In conclusion, this study demonstrates that the use of specific plant residues particularly filter cake and mushroom lumps combined with nutrient-rich animal manures like porcine manure, significantly improves both the physical properties of the growing media and the vegetative growth and yield of Chinese kale in raised bed systems. These findings underscore the agronomic and ecological value of integrating locally available organic wastes into crop production systems. The additive effects observed between plant- and animal-based inputs provide growers with practical flexibility to tailor inputs based on resource availability and production goals. This integrated organic amendment approach offers a sustainable pathway for improving soil health, enhancing crop productivity, and reducing reliance on synthetic fertilizers in leafy vegetable cultivation especially for the raised beds system.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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