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EFFECT OF THREE TYPES OF GROWING MEDIA AND VERMICOMPOST TEA ON THE GROWTH AND INDIVIDUAL WEIGHT OF CHINESE KALE (*Brassica oleracea* var. *alboglabra* Bailey)

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Abstract – *This study aimed to examine the effects of growing media and vermicompost tea on the growth and yield of Chinese kale under pot conditions. Consequently, the experiment of the present study included six treatments, including a control treatment. The results showed that mixing cow manure and vermicompost with growing media and vermicompost tea application had significant positive effects on plant height, number of leaves, stem diameter, and individual weight of Chinese kale plants. The highest plant height, the number of leaves, and individual weight were seen in the T6 treatment [growing media 3 (the mixture of 50% soil, 20% cocopeat, and 30% vermicompost) + vermicompost tea application], but T2 treatment [growing media 2 (the mixture of 50% soil, 20% cocopeat, and 30% cow manure) + no vermicompost tea application] had the highest stem diameter. Noticeably, vermicompost tea application increased the individual weight of the plants in the T4 treatment (growing media of 100% soil + vermicompost tea application) by 119.9%, compared to the control (growing media of 100% soil + no vermicompost tea application). The findings demonstrated that vermicompost tea may have great potential for use as a foliar fertilizer for leaf vegetables to promote growth in plant height and weight.*

Keywords: Brassica oleracea var. alboglabra, Chinese kale, cow manure, poultry manure, vermicompost.

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I. INTRODUCTION

Chinese kale (*Brassica oleracea* var. *alboglabra*) is a biennial plant belonging to the family of Brassicaceae and is popularly grown in China and South Asian countries [1, 2]. Bolting stems and tender rosette leaves of the plant are consumed as common edible parts [1]. In agricultural cultivation, including Chinese kale, intensive fertilizer application is considered an effective way to boost crop productivity. However, continuous and improper use of inorganic fertilizers alone can lead to soil degradation resulting in lower yield, environmental pollution, and harm to human health [3]. Meanwhile, the use of solid organic fertilizers, such as manure, plant residues, biogas residue, spent coffee grounds, cocopeat, or the blend of organic and inorganic fertilizers, can be an effective way to reduce the amount of inorganic fertilizer used for each crop. Organic fertilizers not only maintain soil quality and increase soil organic matter but also improve soil properties, consequently, enhancing crop yield in sustainable farming [4, 5].

Accordingly, the present study strived to examine the influence of using various types of growing media (GM) (mixed soil with organic materials) and/or vermicompost tea (VT) on the productivity of Chinese kale and to find out whether there is a significant interaction between GM and VT (used as foliar fertilizer) on the yield of this type of crop. The results of the present study provide implications for improving the efficiency of recycled organic materials and minimizing pollution by enhancing crop productivity and promoting sustainable crop production, respectively.

II. LITERATURE REVIEW

Organic fertilizers such as animal manure, vermicompost and cocopeat are recognized as soil builders due to their positive benefits on soil health, such as increasing soil organic carbon, soil water holding capacity, and microbial density and improving soil structure and fertility, nutrient holding capacity, soil pH, and the stability of earthworm communities [4–6]. Consequently, application of organic fertilizers can improve yield and quality of crops in agricultural cultivation [4, 5, 7].

Cow manure (a traditional compost) and vermicompost (made from cow manure) are rich organic material sources in Vietnam. Both cow manure and vermicompost contain a high content of the macro elements N, P, and K [8, 9]. However, unlike traditional compost, vermicompost possesses a greater cation exchange capacity and a larger surface area to retain more nutrients [10, 11]. In contrast, cocopeat is a popular and quite cheap agricultural by-product in the South of Vietnam. Nutrients in cocopeat are not as high as those in animal manure and vermicompost [12], but cocopeat is normally applied in crop cultivation to increase water retention and soil porosity. Vietnamese people usually mix cocopeat with soil and manure to make growing medium. Hence, in this present study, cocopeat was mixed with cow manure or vermicompost to create growing medium.

VT is a liquid extract made from vermicompost by mixing it with water and allowing it to ferment for a certain period. VT can be prepared by aerated and non-aerated methods [13, 14]. Molasses, sugars, and other food products can also be added during the extraction of aerated teas to enhance microbial activity [13]. VT is rich in beneficial microbes, NPK, and other nutrient elements and can be used as a foliar fertilizer. VT has been shown to positively affect the yield and quality of crops and promote soil biological activity [15].

Chinese kale (*Brassica oleracea* var. *alboglabra* Bailey) is known as Chinese broccoli and Gai lan. Chinese kale brings health benefits because it possesses a rich content of minerals and bioactive phytochemicals such as glucosinolates, carotenoids, vitamin C, and phenolic compounds [16]. Chinese kale has shown great potential in the prevention of cancer [16, 17].

As mentioned above, excessive use of chemical fertilizers brings severe risks in aspects of human health [3]. Hence, concerns have been raised in public about the safety of food. Using natural organic materials such as GM and foliar organic fertilizer could be an effective method to reduce inorganic application in agriculture to produce safer products.

To sum up, organic fertilizers can enhance crop yields and show a long-lasting effect on agroecosystem productivity and sustainability. Whilst there are studies on the effects of organic fertilizer under the design of a one-factor experiment on Chinese kale [18–20], no previous studies have so far investigated the effect of combinations of growing media (soil mixed with organic materials) and vermicompost tea on the growth and yield of Chinese kale.

III. MATERIALS AND METHOD

The study was carried out from April to June 2023 under pot conditions in a net house of an experimental farm at Tra Vinh University, Tra Vinh Province, Vietnam.

A. The preparation of growing media and vermicompost tea

Growing media preparation

Clay soil with a pH $\sim$ 5.0 was used in this study. Cow manure (slurry), straw, and vermicompost were bought from local farmers. Cow manure was mixed with 1% Trichoderma (10^9 CFU/g) and composted for one month before use in the experiment. The vermicompost was sieved to remove stone or plant residues before being used in the experiment.

The organic GM were prepared by mixing 30% cow manure or 30% vermicompost with 50% soil and 20% cocopeat (v/v) and 0.5% lime ($CaCO_3$). Soil media was made by mixing 100% soil with 0.5% $CaCO_3$. The lime was applied to adjust soil pH to a level of 6.5 – 7.0 and to supply Ca for plants later. 1% of NPK fertilizer 20-20-15 (by weight) was applied to all treatments to ensure that nutrients were sufficient for seedlings at the beginning of the growth period. No further inorganic fertilizers were used to ensure that the plants absorbed nutrients from the organic fertilizers.

After preparation, the different GM were divided into PE pots of C11 size (mouth diameter x height of 27 cm x 23 cm). Each pot contained 8 kg of materials.

Vermicompost tea preparation

VT (aqueous extract) was prepared fresh every 5 days before application using the same type of vermicompost. The extraction ratio of the tea was 1:5 (by volume) vermicompost to water using the method of aerated VT. The exact method of tea preparation was modified from the method of Ingham [13]. One kg of vermicompost was put into a gauze sack and the sack was tied tightly, then put in the 10 L plastic container, and then 5 L clean water and 50 g of molasses were added. After that, the mixture was actively aerated during the 24-hour extraction period by a mini double-nozzle aerating pump (5W VIP-SUN). Before application, the extracted water (VT) was diluted with water in a ratio of 1:4 (by volume) to reduce the concentration of nutrients in the tea. 500 mL of diluted VT was used for one plant (one pot) in each application.

B. Preparation of transplants

The Chinese kale TN66 seeds used in this study were from a commercial supplier (Trang Nong Seeds Co., LTD, Ho Chi Minh City, Vietnam). The seeds were initially germinated. When the seedlings had grown to have three true leaves, they were transplanted into the PE pots.

C. Experimental design

The two-level factorial experiment was conducted to assess how GM and VT impact the growth and yield of Chinese kale under pot conditions. Three types of different mixtures of GM were used in this present study (different materials mixed by volume), as described below:

GM1: 100% soil

GM2: The mixture of 50% soil, 20% cocopeat and 30% cow manure

GM3: The mixture of 50% soil, 20% cocopeat and 30% vermicompost

Plants in all three GM were then further treated with either no VT application or with vermicompost application. Consequently, the present experiment included six treatments, including control, as follows:

T1: GM1 + no VT application (control)

T2: GM2 + no VT application

T3: GM3 + no VT application

T4: GM1 + VT application

T5: GM2 + VT application

T6: GM3 + VT application

Treatments were replicated eight times. Each replicate was an individual pot containing 8 kg of GM, and each pot was planted with 1 seedling.

Vermicompost tea application

VT was used as a foliar fertilizer. The tea was applied every 5 days until 30 days after planting. For VT treatments, each planted pot was sprayed with 500 mL of diluted VT produced as described above.

Data collection

All growth and yield parameters were determined at the harvested point 36 days after planting. The individual growth parameters of the plants, including plant height, stem diameter, and the number of mature leaves were investigated. The yellow leaves and roots were then removed, and all of the plants were harvested on the same day. Weighing the plant shoots allowed us to calculate each plant's fresh biomass. In addition, the root fresh weight from a single plant was then determined.

D. Data analysis

Statistical analysis was conducted with SPSS vs. 22 (IBM Inc.). A one-way ANOVA determined the significance of differences between treatments in the growth and yield parameters of Chinese Kale. Levene's test was used to analyze for homogeneity of variance of the data set to ensure that all comparison groups had the same variance before analyzing ANOVA. Turkey's HSD post-hoc test at $p < 0.05$ was used to determine the significance amongst individual treatments.

The significance of the main effects of GM and VT and the interaction term of main effects on the growth and yield parameters of Chinese kale plants were also determined by two-way ANOVA analysis.

IV. RESULTS AND DISCUSSION

A. Effect of growing media and vermicompost tea on the plant height of Chinese kale

There were differences in the height of the Chinese kale plant amongst the treatments after 36 days. The plant heights in the treatments that used VT were higher than in corresponding treatments without using VT. The treatment of T6 [GM3 (the mixture of 50% soil, 20% cocopeat, and 30% vermicompost) + using VT] had the highest growth in the plant height. In contrast, the lowest growth was recorded in the control [T1 treatment: GM1 (100% soil) + no VT]. Consequently, the results of a one-way ANOVA analysis showed significant differences in plant height amongst treatments ($p < 0.001$). The plant height of Chinese kale in the treatments of GM2 and GM3 with/without VT was significantly higher than that in the T1 treatment (100% soil and no application of VT) (Table 1).

In terms of the effects of the main variables, both GM and VT had significant positive influences on plant height (Table 1). The application of VT significantly increased the height of Chinese kale compared to no VT application ($p = 0.012$). Mixing organic material into the GM (GM2 and GM3) led to improved plant growth in terms of height in comparison with the growing medium of 100% soil ($p < 0.001$). However, no significant interaction term effect of GM and VT on the plant height was shown in this present study through two-way ANOVA analysis ($p = 0.94$).

B. Effect of growing media and vermicompost tea on the number of leaves of Chinese kale

Table 2 revealed differences in the number of leaves on Chinese kale plants across different treatments. The results of the one-way ANOVA analysis indicated a significant difference in the number of leaves per plant among the treatments ($p = 0.029$). In particular, the number of leaves per single plant in the T6 treatment (10.13 leaves) was significantly higher than that in the T1 treatment (8.25 leaves).

Table 1: Effect of growing media (GM) and vermicompost tea (VT) the plant height of Chinese kale plants (cm)

VT	GM			
	GM1	GM2	GM3	***Mean of VT***
No VT	27.75 ± 3.15^{c}	36.75 ± 4.56^{ab}	39.25 ± 5.18^{a}	34.58 ± 6.55^{B}
Yes VT	31.75 ± 5.99^{bc}	40.38 ± 4.17^{a}	42.13 ± 0.09^{a}	38.08 ± 6.54^{A}
Mean of GM	29.75 ± 5.07^{Y}	38.56 ± 4.62^{X}	40.69 ± 4.74^{X}	
$P_{(VT)} = 0.012$				
$P_{(GM)} < 0.001$				
$P_{(VT)} \times P_{(GM)} = 0.94$				

Note: Values are mean ± S.D of eight replications; GM1: 100% soil; GM2: The mixture of 50% soil, 20% cocopeat and 30% cow manure; GM3: The mixture of 50% soil, 20% cocopeat and 30% vermicompost. The treatments followed by the same letter were not significantly different, whilst differences amongst treatments were shown by different lowercase letters, differences amongst main effects were shown by capital letters.

Table 2: Effect of growing media (GM) and vermicompost tea (VT) on the number of leaves of Chinese kale plants

VT	GM			
	GM1	GM2	GM3	***Mean of VT***
No VT	8.25 ± 1.16^{b}	9.50 ± 1.41^{ab}	9.88 ± 0.99^{ab}	9.21 ± 1.36
Yes VT	9.88 ± 1.13^{ab}	8.88 ± 1.64^{ab}	10.38 ± 1.41^{a}	9.71 ± 1.49
Mean of GM	9.07 ± 1.39	9.19 ± 1.52	10.13 ± 10.21	
$P_{(VT)} = 0.193$				
$P_{(GM)} = 0.053$				
$P_{(VT)} \times P_{(GM)} = 0.063$				

Note: Values are mean ± S.D of eight replications; GM1: 100% soil; GM2: The mixture of 50% soil, 20% cocopeat and 30% cow manure; GM3: The mixture of 50% soil, 20% cocopeat and 30% vermicompost. The treatments followed by the same letter were not significantly different.

However, main effects analysis by two-way ANOVA showed no significant effects of GM and VT on the number of leaves per plant ($p = 0.053$ and $p = 0.193$, respectively). The interaction between the effects of GM and VT on the number of leaves per plant was not statistically significant ($p = 0.063$).

C. Effect of growing media and vermicompost tea on the stem diameter of Chinese kale

Differences in the mean stem diameter of Chinese kale plants among treatments were variable (Table 3) and statistical analysis of a one-way ANOVA demonstrated that the differences noted among treatments were significant ($p < 0.001$). The highest stem diameter of Chinese plants (1.99 cm) was found in the treatment of GM2 + no VT application but did not differ significantly from the treatments of GM2 + VT application and GM3 + VT application. By contrast, the Chinese kale plants in treatments GM1 with/without VT application had the lowest stem diameter (Table 3).

Table 3: Effect of growing media (GM) and vermicompost tea (VT) on the stem diameter of Chinese kale plants (cm)

VT	GM			
	GM1	GM2	GM3	*Mean of VT*
No VT	1.19 ± 0.31^{c}	1.99 ± 0.25^{a}	1.56 ± 0.18^{bc}	1.58 ± 0.41
Yes VT	1.34 ± 0.31^{c}	1.76 ± 0.26^{ab}	1.80 ± 0.22^{ab}	1.63 ± 0.33
Mean of GM	1.27 ± 0.31^{Y}	1.88 ± 0.27^{X}	1.68 ± 0.23^{X}	
$P_{(VT)} = 0.473$				
$P_{(GM)} < 0.001$				
$P_{(VT)} \times P_{(GM)} = 0.036$				

Note: Values are mean ± S.D of eight replications; GM1: 100% soil; GM2: The mixture of 50% soil, 20% cocopeat and 30% cow manure; GM3: The mixture of 50% soil, 20% cocopeat and 30% vermicompost. The treatments followed by the same letter were not significantly different, whilst differences amongst treatments were shown by different lowercase letters, differences amongst main effects were shown by capital letters.

The results of the two-way analysis of variance showed the effect of VT on the stem diameter was not significant, but the effect of GM was significant ($p = 0.473$ and $p < 0.001$, respectively). The GM mixed with cow manure (GM2) had the highest mean stem diameter (1.88 cm), significantly higher than that in the GM1 treatment (1.27 cm), but not significantly different from the GM3 treatment (1.69 cm) (Table 3). However, the interaction term between GM and VT was significant ($p = 0.036$), indicating there was a difference in the effect of GM by VT.

It is well-established that organic materials such as cattle manure and vermicompost have positive effects in promoting plant growth [5, 21, 22]. Masarirambi et al. [21] demonstrated that applications of cattle manure at rates of 20 t ha^{-1}, 40 t ha^{-1}, and 60 t ha^{-1} significantly increased the height, the number of leaves and leaf area of traditional okra (*Corchorus olitorius* L.) in comparison with the control (application of 150 kg inorganic fertilizer). Another previous study indicated that the application of different doses of vermicompost and chemical fertilizers increased the shoot length and number of leaves of tomato plants during different growth intervals in comparison with the control [23]. Particularly, at the harvest, the shoot length of the plants in the treatments of the highest application rate of vermicompost (20 t ha^{-1}), and NPK fertilizer (200%) was increased by 36.34 cm and 23.34 cm, respectively, as compared to control. A vermicompost application rate of 20 t ha^{-1} resulted in the highest plant height with 52.67 cm [23]. Similarly, the application of VT (used to irrigate plants) increased broccoli plant height by 84.3% as compared to the control [24]. Meanwhile, a combination between vermicompost (8 t ha^{-1}) and VT raised the plant height by 126.4% [24]. These findings agree with the results of this present study; mixing organic matter in the form of cow manure and vermicompost into the GM and applying VT significantly increased the height of Chinese kale plants (Table 1). In addition, GM had a significant influence on the stem diameter of the plant (Table 3). This is because cow manure, vermicompost and VT are rich in NPK and other minerals [8, 9, 15]. Also, vermicompost and VT contain plant growth-regulating hormones and crucial soil enzymes [25]. As a result, these materials strongly stimulated the plant growth.

D. Effect of growing media and vermicompost tea on the individual weight of Chinese kale plants

There were large differences among treatments in the individual mean plant weight at harvest (Table 4; Figure 2). The research results indicated that GM and VT increased the individual weight of Chinese kale plants. The highest weight of a sole plant was found in the T6 treatment (GM3 + VT application) with a mean of 133.35 g, an increase of 361.74% compared to the control (T1 – GM1 + no VT application).

Table 4: Effect of growing media (GM) and vermicompost tea (VT) on the individual weight of Chinese kale plants (g)

VT	**GM**			
	GM1	GM2	GM3	***Mean of VT***
No VT	28.88 ± 4.53^{d}	112.17 ± 19.11^{ab}	101.75 ± 13.59^{b}	80.93 ± 40.08^{B}
Yes VT	63.50 ± 22.76^{c}	112.79 ± 18.58^{ab}	133.35 ± 19.63^{a}	103.21 ± 35.73^{A}
Mean of GM	46.19 ± 23.90^{Y}	112.48 ± 18.21^{X}	117.55 ± 23.07^{X}	
		$P_{(VT)} < 0.001$		
		$P_{(GM)} < 0.001$		
		$P_{(VT)} \times P_{(GM)} = 0.015$		

Note: Values are mean ± S.D of eight replications; GM1: 100% soil; GM2: The mixture of 50% soil, 20% cocopeat and 30% cow manure; GM3: The mixture of 50% soil, 20% cocopeat and 30% vermicompost. The treatments followed by the same letter were not significantly different, whilst differences amongst treatments were shown by different lowercase letters, differences amongst main effects were shown by capital letters.

An increase of 30.06% in the individual weight of plants in the T6 treatment compared to the T5 treatment (GM3 + no VT application) was found. Similarly, the individual weight of Chinese kale plants in the T4 treatment (GM1 + VT application) was raised by 119.88% in comparison with the T1 treatment (GM1 + no VT application). However, the average weight of a single plant was similar in the T2 (GM2 + no VT application) and the T5 (GM2 + VT application) treatments (Table 4). Consequently, the statistical analysis by one-way ANOVA confirmed significant differences in the individual weights of Chinese kale plants among treatments ($p < 0.001$).

Regarding main effects, both the variables of GM and VT had significant influences on the average weight of Chinese kale plants ($p < 0.001$ and $p < 0.001$, respectively), indicating that mixing organic matter in the GM and using VT increased the yield of the plants. Moreover, the interaction term (GM*VT) was found to be significant ($p = 0.015$), indicating that there was a variation in the effect of VT application on plant weight based on the different growth media used (Table 4).

Fig. 1: Size of Chinese kale plants in different treatments: T1: GM1 + no VT application (Control); T2: GM2 + no VT application; T3: GM3 + no VT application; T4: GM1 + VT application; T5: GM2 + VT application; T6: GM3 + VT application

Positive effects of organic fertilizers such as cow manure, vermicompost and VT on the yield of crops were reported in previous studies [21, 23, 24]. Masarirambi et al. [21] found that there was a positive relationship between the cattle manure dose and the mean fresh mass of whole plants and marketable fresh mass (shoot fresh mass). The highest fresh mass for whole plants and shoot fresh mass (with 1276.53 g and 77.60 g, respectively) was recorded in the manure treatment of 60 t ha^{-1}, an increase of 90.5% and 145.6%, respectively in comparison with the inorganic fertilizer treatment (control). In addition, treatments of soil mixed with 8 t ha^{-1} and 16 t ha^{-1} vermicompost combined with half the recommendation of 120 kg DAP ha^{-1} had higher weights of broccoli main flower than in a treatment of 240 kg DAP ha^{-1} only [24]. Spraying VT in combination with 120 kg DAP ha^{-1} significantly increased the weight of the main flower disc by 30.58%, as compared to the chemical fertilizer treatment of 240 kg DAP ha^{-1}; i.e., the flower disc archived a weight of 834.7 g with VT treatment and 639.2 g with only inorganic fertilizer treatment [24]. The study of Alkobaisy et al. [24] also showed that a combination of vermicompost of 8 t ha^{-1}, VT and 120 kg ha^{-1} DAP had the highest broccoli main flower weight (865.8 g). Similar results were confirmed in the study of Kashem et al. [23]. The results of this study showed that cow manure/vermicompost application to soil at 5, 10, 15, and 20 t ha^{-1} increased significantly the mean fresh weight of tomato *Solanum lycopersicum* L. (ranged from 7.9 g in 5 t ha^{-1} to 40 g in 20 t ha^{-1}), as compared to control treatment with only 1.34 g [23].

This present study also demonstrated that mixing cow manure and vermicompost with soil increased significantly the mean individual weight of Chinese kale plants, as compared to the GM of 100% soil (Table 4). Furthermore, spraying VT also promoted the mean individual weight of Chinese kale. As a result, the T6 treatment (GM3 + VT application) resulted in the plants with the highest average individual weight.

However, it is noted that the application of VT with GM mixed with cow manure (GM2) did not raise the shoot weight of Chinese kale. In addition, the plants grown in the treatment with GM2 had larger stem diameters than those in the GM3 (GM mixed with vermicompost) (Table 3). This may be due to the fact that vermicompost and VT contain plant growth-regulating hormones [25]; thus, it stimulated the plant height rather than the plant stem diameter.

In general, the positive effects of organic materials on the growth and the shoot weight of Chinese kale in this present study is because organic materials contain high contents of NPK, have a great cation exchange capacity and a large surface area to retain more nutrients and improve soil parameters [4–6, 8–11, 26]. In particular, it is well-documented that the content of macronutrients (NPK) and micronutrients in vermicompost is higher than that in conventional compost like cattle dung/cow manure compost [11, 27]. Phytohormones and crucial enzymes (such as amylase, chitinase, cellulase, and lipase which help to break down organic matter to release available nutrients for plants) are also presented in vermicompost and vermicompost tea [15, 25]. Another important property is that the nutrient-retaining capacity of vermicompost is greater than that of conventional compost [10, 11, 27]; thus, plants will have more available nutrients to intake. As a result, either the treatment of GM3 (GM mixed with vermicompost) or the treatment of VT application in this present study gave better growth parameters in plant height, number of leaves, and mean individual weight of Chinese kale in comparison to the treatments of GM1 (100% soil), GM2 (GM mixed with cow manure), and no VT application.

V. CONCLUSION

GM and VT had significant positive effects on the growth and yield of Chinese kale plants. Whilst the highest plant height, number of leaves, and individual weight were recorded in the T6 treatment (GM3 + VT application), the T2 treatment (GM2 + no VT application) had the highest stem diameter (1.99 cm). In particular, the highest individual weight of a plant was found in the T6 treatment with a mean of 133.35 g, an increase of 361.74% compared to the control (GM1 + no VT application). Therefore, the results of this study suggest that VT holds significant promise as a foliar fertilizer, as it has the potential to enhance both the height and weight of leafy vegetable plants.

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