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GROWTH AND YIELD RESPONSES OF WHITE CABBAGE INFLUENCED BY VERMICOMPOST TEA AND VERMICOMPOST TEA RESIDUE

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Abstract: White cabbage (*Brassica oleracea* var. *capitata*) is one of the oldest known vegetable crops and is commonly grown worldwide. Vermicompost tea (VCT) is considered a biofertiliser and is used in sustainable agriculture to promote crop yield and improve soil properties. This study was conducted to assess the efficacy of VCT and VCT residue (the solid material remaining after producing VCT) and their competency to partly replace inorganic fertilisers for the growth and yield of white cabbage under field conditions. The results showed that the use of VCT at an extraction ratio of 1:5 combined with 50% inorganic fertiliser significantly increased the cabbage head diameter and mean individual weight at harvest compared to the 100% inorganic fertiliser treatment. Noticeably, the application of VCT in a 1:5 combination with VCT residue + 50% inorganic fertilisers and VCT in a 1:10 combination with VCT residue + 50% inorganic fertilisers showed the best performances among treatments, with significant increases in the 3-m^2 plot yield of 24.7%, and 14.3%, respectively, compared to the treatment with 100% inorganic fertilisers. These results demonstrate that VCT combined with VCT residue can replace a substantial proportion of inorganic fertilisers in cabbage cultivation, thereby reducing reliance on these non-sustainable products while recycling waste materials in sustainable agriculture.

Key words: *Brassica oleracea* var. *capitata*, cabbage, organic fertilisers, vermicompost tea, vermicompost tea residue.

Introduction

There is no doubt that agricultural production is influenced by several factors such as soil condition, soil fertility, climate conditions, plant diseases, and irrigation conditions. Inorganic fertiliser is one of the most important input factors contributing to increased crop productivity, thanks to its outstanding

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advantages in providing nutrients quickly and accurately. However, it is well-documented that excessive or improper use of chemical fertilisers in intensive cultivation has led to detrimental influences on soil quality, plants, and the environment, such as soil acidification, increased soil compaction, water pollution, increases in pest and disease problems, and a reduction in the number of soil organisms (Chali Abate, 2023). By contrast, organic fertilisers are derived from natural sources such as manure, plant residues, coffee grounds, and spent mushroom material. They are slow-release fertilisers, allowing soil microorganisms time to break down organic materials and release essential plant nutrients such as nitrogen, phosphorus, potassium, and micronutrients. Hence, organic fertilisers provide stable and long-term nutrition, helping plants absorb nutrients steadily and avoiding sudden excesses or deficiencies. In addition, organic fertilisers help supply organic matter and beneficial microorganisms, improve soil structure, increase soil porosity, increase soil water retention and drainage capacity, and improve soil pH (Assefa and Tadesse, 2019). Therefore, managers, scientists, and farmers are interested in finding organic and sustainable alternatives to conventional agrochemicals.

Due to the low nutrient content and slow-release properties of organic fertilisers, using them as a complete replacement for inorganic fertilisers could lead to nutrient deficiencies in modern crop varieties with high nutritional needs. In such cases, a large amount of organic fertiliser must be applied to meet the nutrient requirements of these crops. Research indicates that combining organic and inorganic fertilisers can increase crop productivity and quality, improve soil quality, and enhance nutrient efficiency (Khanam et al., 2022; Phillips et al., 2022; Wang et al., 2025). The sole use of organic or inorganic fertiliser cannot increase crop yields and improve soil health. Wang et al. (2025) indicated that the incorporation of manure and chemical fertiliser in wheat–wheat–maize rotation systems increased the sustainable yield index (SYI) of grain yield of maize and wheat compared to that of chemical application only in three long-term fertilisation experiments in China. Furthermore, a previous study demonstrated that the potential of integrating organic and inorganic fertilisers as a sustainable alternative to conventional inorganic fertiliszation. Combined organic and inorganic fertilisers not only reduced inorganic fertiliser use by 40% while achieving similar tomato fruit quality and quantity, but also improved the soil properties (Hernández et al., 2014).

Vermicompost (VC) is a higher-quality final product produced through the conversion of organic matter into humus-like material by earthworms (Amante, 2024). The macromineral contents of nitrogen, phosphorus, and potassium in VC are 1.5–2.5%, 0.9–1.7%, and 1.5–2.4%, respectively (Kumar et al., 2019). Due to its high content of nutrients, organic matter, humic acid, plant-growth hormones, a low C:N ratio, and a variety of beneficial microorganisms, VC significantly enhances crop growth and productivity while improving soil properties (Mohite et al., 2024; Amante, 2024). Consequently, it is widely recognised as an effective biofertiliser for sustainable agricultural cultivation (Mohite et al., 2024; Amante, 2024).

Vermicompost tea (VCT) is an organic liquid fertiliser produced by fermenting vermicompost with water for a certain period. Both aerated and non-aerated methods can be used in VCT fermentation, with supplemental nutrients such as molasses, sugars, and yeast extract added to enhance microbial activity (Ingham, 2005). Studies have shown that VCT effectively promotes plant growth and yield, improves soil properties, and suppresses plant diseases and pests due to its abundance of beneficial microbes, NPK, and other nutrient elements (Pant et al., 2012; Che Sulaiman and Mohamad, 2020; Alkobaisy et al., 2021). Research by Luu et al. (2023a) demonstrated that spraying 500 mL of 5% VCT every five days increased the individual weight of Chinese kale plants by 27.5% compared to no VCT application. Additionally, the study by Souffront et al. (2022) revealed that using 200 mL of VCT per tomato plant via soil drenching with concentrations of 10% and 20% resulted in heavier tomato fruit weight and higher total marketable yield compared to the 5% VCT treatment and the control (no VCT application). Furthermore, after brewing and filtering to collect VCT, the solid organic material residue (referred to as VCT residue) can be applied to soil or plants. However, no previous studies have demonstrated its efficacy in agricultural cultivation.

White cabbage (*Brassica oleracea* var. *capitata*) belongs to the Brassicaceae family and is one of the oldest known vegetables. Cabbage is a biennial plant, but is commonly grown as an annual crop, characterised by dense-leaved heads (Stefan and Ona, 2020; Chanu et al., 2025). Cabbage is popularly cultivated globally, including Vietnam, and has high commercial value (Chanu et al., 2025). Due to its high content of fibre, minerals, vitamins, and antioxidants, white cabbage provides several health benefits, including anti-cancer activity, improved gastrointestinal health, antioxidant activity, anti-obesity, hypolipidaemic, and hypoglycaemic effects (Stefan and Ona, 2020).

There is strong evidence that VCT has significant potential as an organic foliar fertiliser for various crops, effectively increasing production and supporting the sustainability of agricultural systems. However, no previous studies have assessed the effectiveness of the VCT residue in enhancing crop yield. As a result, the present study investigated the growth-promoting efficiency of VCT and VCT residue on the growth and yield of the plant *Brassica oleracea* var. *capitata*. The study results could demonstrate the effectiveness of VCT individually and in combination with VCT residue in enhancing crop yields by recycling nutrients from waste products. This not only improves crop yields but also helps maintain environmental sustainability in farming.

Material and Methods

This study was conducted under field conditions from October 2024 to January 2025 in Cang Long commune, Vinh Long province, Vietnam. The soil at the experimental site is classified as loam with a pH of approximately 5.5.

Field preparation and fertiliser application

The field was ploughed, levelled, and formed into ridges for transplanting seedlings. Each ridge was 20 cm high above the field surface and 1 m wide. Between two adjacent ridges, there was a 15-cm-wide furrow to facilitate drainage and maintenance of the experiment. The experimental area was divided into plots of 3 m^2.

To produce white cabbage in this experiment, the local cultivation practice followed by the local farmers in Cang Long commune was applied. An inorganic NPK fertiliser (for the top-dressing period) was used with a formula of 180 N, 120 P_2O_5, and 120 K_2O (kg/ha).

Table 1. Top-dressing fertilisers used in the experiment.

Day after planting	Inorganic fertiliser application (kg/ha)							Note
	T1	T2	T3	T4	T5	T6	T7	
10	400	200	200	200	200	200	200	NPK (20–10–10)
20	200	100	100	100	100	100	100	
40	350	175	175	175	175	175	175	NPK (17–17–17)

Source: Authors' calculations. T1–T7: Seven treatments of this experiment.

Noticeably, for basal fertilisation, all treatments applied the same amount and type of fertiliser (per 1 ha), including: 15 tonnes of composted manure, 200 kg of phosphate fertiliser (16%, containing 32 kg of P_2O_5), and 100 kg of calcium-magnesium fertiliser (Sao Vang Mekong Company, Vietnam). Calcium-magnesium fertiliser helps stabilise pH, improve soil, and provide micronutrients for crops. For top-dressing fertilisation, the amount and type of top-dressing fertiliser depended on each treatment. The time and dosage of inorganic top-dressing fertilisers are presented in Table 1.

Vermicompost tea (VCT) was applied by spraying at a rate of 200 mL per plant at different dilution levels corresponding to the treatments. After the cabbage head formed, VCT was irrigated at the plant base to prevent it from remaining on the head. VCT residue was used at a rate of 200 g per plant and distributed around the base of each plant. VCT and VCT residue applications were made every 7 days. The first and last applications of VCT and VCT residue were made 10 days and 44 days after planting, respectively. Treatment T1 received 100% of the top-dressing fertilisers; the remaining treatments (T2 to T7) received inorganic top-dressing fertiliser at 50% of the application rate used in treatment T1, supplemented either with VCT alone or in combination with VCT residue. A 20–10–10 NPK fertiliser (Yaramila PLUS) was used 10 and 20 days after planting, and a 17–17–17 NPK fertiliser (Viet Duc Fertilizer Company, HCM City, Vietnam) was used 40 days after planting.

Preparation of the transplants

This study used heat-tolerant white cabbage seeds (TROPIC-SUNPLUS F1; Chanh Nong Company, Vietnam). The seeds were sown in an 84-hole foam seedling tray with a growing medium consisting of coconut peat, rice husk ash, and clean loam soil in a ratio of 1:1:1. On the 7th and 14th day after seedling, fish fertiliser (concentration of 1%) was applied. Transplants were planted when they had 4–6 true leaves.

Experimental design

To assess the efficiency of vermicompost tea (VCT) and vermicompost tea residue (VCT residue) on the growth and the yield of white cabbage (*Brassica oleracea* var. *capitata*), a one-factor experiment was conducted using a completely randomised design (CRD) under field conditions. The experiment included seven distinct treatments, as follows:

T1: 100% top-dressing inorganic fertilisers (control)

T2: Vermicompost tea at an extraction ratio of 1:5 + 50% inorganic top-dressing fertilisers (VCT 1:5)

T3: Vermicompost tea at an extraction ratio of 1:10 + 50% inorganic top-dressing fertilisers (VCT 1:10)

T4: Vermicompost tea at an extraction ratio of 1:15 + 50% inorganic top-dressing fertilisers (VCT 1:15)

T5: Vermicompost tea at an extraction ratio of 1:5 with adding 200 g plant^{-1} of vermicompost tea residue + 50% inorganic top-dressing fertilisers (VCT 1:5 + VCT residue)

T6: Vermicompost tea at an extraction ratio of 1:10 with adding 200 g plant^{-1} of vermicompost tea residue + 50% inorganic top-dressing fertilisers (VCT 1:10 + VCT residue)

T7: Vermicompost tea at an extraction ratio of 1:15 with adding 200 g plant^{-1} of vermicompost tea residue + 50% inorganic top-dressing fertilisers (VCT 1:15 + VCT residue)

The treatments were replicated three times. Each replication consisted of a plot of 3 m², planted with 10 seedlings at a spacing of 50 cm × 70 cm between plants.

Vermicompost tea preparation

Vermicompost tea (aqueous extract) was freshly prepared every 7 days before application, using the same type of vermicompost. The vermicompost was obtained from Dang Gia Trang Production Trading Services Company Limited (HCM city, Vietnam), and contained 48.4% organic matter, 1.57% nitrogen, 1.24% available phosphorus, and 0.67% available potassium.

The extraction ratios for the tea were 1:5, 1:10, and 1:15 (w/v) of vermicompost to water, employing the aerated method. This preparation method was modified from the method of Ingham (2005). Vermicompost (VC) was placed into a gauze sack, which was then tied tightly and put in a suitable plastic container. Dechlorinated water was added in appropriate volumes to achieve the desired vermicompost tea dilutions, along with 5% molasses (calculated based on the percentage of the vermicompost quantity). The mixture was then actively aerated for a 24-hour extraction period using a mini double-nozzle aerating pump. After the fermentation process, 200 mL of vermicompost tea, with extraction ratios of 1:5 (VCT 20%), 1:10 (VCT 10%), and 1:15 (VCT 6.7%), were used as a foliar fertiliser to spray each plant for the respective treatments. When the plant leaves began to compact to form the cabbage head, the vermicompost tea was applied at the plant base. Vermicompost tea residue remaining after VCT extraction was also applied at a rate of 200 g per plant in treatments T5–T7.

Data collection

Five of the 10 plants in each plot were selected randomly to collect data. The growth parameters, including plant height (cm), stem diameter and foliage diameter (cm) of cabbage plants were recorded every 10 days after planting. The number of cabbage leaves was counted at 10 and 20 days after planting, until the cabbage plants began to form heads. The diameter of the cabbage head was measured at 40, 50, and 56 days after planting. The yield parameters were determined on the harvest day (56 days after planting). In terms of yield parameters, cabbage heads were harvested on the harvest day. The fresh mean weight of cabbage heads was determined from the five selected plants per plot, representing individual plant yield, while plot yield was calculated as the total fresh weight of all ten plants within each plot.

Data analysis

Statistical analysis was conducted using SPSS *v.* 22 (IBM Inc.). One-way ANOVA was used to determine the statistical significance of differences in growth and yield parameters of white cabbage plants among different treatment groups.

Before comparing the means of all treatments, the data sets were analysed for homogeneity of variance with the Levene's test to ensure that all comparison groups had the same variance. When this assumption was not met, the Welch's test was used as an alternative analysis. The significance of the effects of VCT and VCT residue on the growth and yield of cabbage plants among treatments was determined by the Duncan's *post-hoc* test at $p < 0.05$.

Results and Discussion

Effects of vermicompost on the growth parameters of white cabbage

Differences in the plant height, foliage diameter, the number of leaves and the diameter of cabbage head among the seven different treatments during the experimental period are shown in Tables 2, 3, and 4.

In general, insignificant differences in cabbage plant height among treatments were observed at most sampling points during the growing period, the exception being at 20 days after planting (Table 2). At 10 days after planting, there were no significant differences in plant height among treatments. However, the application of VCT and VCT residue at this stage began to influence plant growth. By 20 days after planting, cabbage plants treated with VCT and/or VCT residue had been taller than those in the treatment receiving only inorganic fertiliser, as confirmed by one-way ANOVA (Table 2). The analysis showed significant differences in plant height among treatments, with those receiving VCT and/or VCT residue generally outperforming the control (inorganic fertiliser only), except for treatment T2. From 30 days after planting onwards, the plants began forming cabbage heads, which may explain the reduced variation in plant height among treatments during the later stages (30 to 56 days). Consequently, no significant differences in plant height were detected among treatments during these periods (Table 2).

Vermicompost tea (VCT) and VCT residues positively influenced the foliage diameter of cabbage plants in this study (Table 3). After the application of VCT and VCT residues, the foliage diameter of plants in these treatments was greater than that of plants treated with 100% inorganic fertiliser. Notably, at 20 days after planting, the foliage diameter in the inorganic fertiliser-only treatment was significantly lower than in all treatments that received VCT and/or VCT residues.

Table 2. Effects of vermicompost tea and vermicompost tea residue on the height of white cabbage plants.

Treatments	Plant height (cm) in different growth periods					
	10 days	20 days	30 days	40 days	50 days	56 days
T1 (control)	10.13	13.13b	21.87	24.87	31.20	31.40
T2	9.80	14.07ab	20.20	25.87	31.87	33.80
T3	10.53	15.97a	22.37	25.87	29.4 0	32.33
T4	10.00	16.07a	22.10	29.13	32.27	34.30
T5	10.13	16.20a	22.27	28.53	31.73	33.40
T6	9.07	16.37a	22.80	27.80	31.93	34.00
T7	9.77	16.23a	22.90	27.87	30.93	31.60
$F_{(6,14)}$	0.698	3.274	0.434	1.279	0.873	1.527
Sig.	ns	*	ns	ns	ns	ns
CV (%)	9.5	8.0	10.8	9.0	5.7	5.0

Values are means of three replications; *ns*: non-significant; *: statistically significant at the 5% level; means with different letters are significantly different at $p < 0.05$ according to the Duncan's *post hoc* test.
Source: Authors' calculations.

Furthermore, at 30 days after planting, the foliage diameter of cabbage plants in treatments receiving VCT alone or in combination with VCT residues increased by 17.00% to 31.88% compared with the inorganic fertiliser-only treatment (control). This trend continued up to 40 days after planting. However, by 40 days and at harvest (56 days after planting), the differences in foliage diameter between the VCT and/or VCT residue treatments and the control had decreased considerably (Table 3).

Table 3. Effects of vermicompost tea and vermicompost tea residue on the foliage diameter of cabbage plants.

Treatments	Foliage diameter (cm) in different growth periods					
	10 days	20 days	30 days	40 days	50 days	56 days
T1 (control)	17.70	24.07b	36.95	48.43c	55.90	59.57
T2	14.43	27.73a	44.53	48.90bc	60.93	62.70
T3	15.80	27.67a	43.23	51.30abc	56.50	59.13
T4	14.60	27.13a	46.60	54.10a	57.97	61.97
T5	16.83	27.90a	48.03	54.10a	59.30	62.77
T6	16.27	28.57a	47.37	55.47a	59.50	61.73
T7	16.27	28.60a	48.73	53.37ab	58.77	60.80
$F_{(6,14)}$	0.853	5.450	2.777	3.516	2.380	0.959
Sig.	ns	**	ns	*	ns	ns
CV (%)	13.7	4.2	9.4	4.9	3.4	4.2

Values are means of three replications; *ns*: non-significant; *: statistically significant at the 5% level; **: statistically significant at the 1% level; means with different letters are significantly different at $p < 0.05$ according to the Duncan's *post hoc* test.
Source: Authors' calculation.

After VCT and VCT residue application, there were differences in the stem diameter parameter between the inorganic fertiliser-only control and treatments with VCT alone or combined with VCT residue (Table 4). Subsequent statistical analysis confirmed significant differences in the stem diameter among the treatments at 20 days after planting. However, after 20 days, these differences diminished during the following growth periods. Consequently, statistical analysis indicated no significant differences in stem diameter of cabbage plants among treatments between 30 and 56 days after planting (Table 4).

Table 4. Effects of vermicompost tea and vermicompost tea residue on the stem diameter of cabbage plants.

Treatments	Stem diameter (cm) in different growth periods					
	10 days	20 days	30 days	40 days	50 days	56 days
T1 (control)	0.43	0.93b	1.38	2.06	2.24	2.38
T2	0.41	0.99b	1.37	1.93	2.28	2.53
T3	0.47	0.99b	1.41	2.00	2.17	2.47
T4	0.40	1.14a	1.41	1.99	2.26	2.45
T5	0.45	1.13a	1.41	1.95	2.24	2.52
T6	0.43	1.16a	1.42	2.00	2.28	2.40
T7	0.43	1.21a	1.43	2.03	2.26	2.45
$F_{(6,14)}$	0.275	5.881	0.045	0.344	0.846[1]	0.513
Sig.	ns	**	ns	ns	ns	ns
CV (%)	17.9	7.2	13.5	6.3	2.4	5.46

Values are means of three replications; *ns*: non-significant; *: statistically significant at the 5% level; **: statistically significant at the 1% level; [1]: $F_{(Welch's\ test)}$; means with different letters are significantly different at $p < 0.05$ according to the Duncan's *post hoc* test.
Source: Authors' calculation.

Differences in the number of cabbage leaves per plant among treatments are shown in Table 5. Since approximately 30% of the cabbage plants had already begun forming heads by 30 days after planting (with leaves compacting to form the cabbage head), leaf count data were recorded only at 10 and 20 days after planting. On day 10, there were no significant differences in the number of leaves among treatments. However, by day 20, treatments involving VCT and VCT residue had shown a higher number of leaves compared to the treatment receiving inorganic fertiliser only. Among these, treatment T6 recorded the highest number of leaves (11.13), representing a 31.40% increase compared to T1 (inorganic fertiliser only). One-way ANOVA analysis confirmed that the number of leaves differed significantly among treatments on day 20, and *post hoc* testing showed that the number of leaves in treatments T5 (50% inorganic fertiliser + VCT 1:5 + VCT residue) and T6 (50% inorganic fertiliser + VCT 1:10 + VCT residue) were significantly higher than in T1(inorganic fertiliser only).

Table 5. Effects of vermicompost tea and vermicompost tea residue on the number of leaves and the diameter of cabbage heads.

Treatments	The number of cabbage leaves		The diameter of cabbage head (cm)		
	10 days	20 days	40 days	50 days	56 days
T1 (control)	6.00	8.47b	9.80	15.10	16.93b
T2	4.80	8.67b	7.47	15.53	18.20a
T3	5.27	9.33ab	9.00	14.27	16.73b
T4	4.93	9.33ab	9.93	14.73	17.07b
T5	5.40	10.73a	10.93	17.20	19.03a
T6	5.73	11.13a	9.40	15.93	18.10a
T7	5.33	10.40 ab	8.67	15.40	16.67b
$F_{(6,14)}$	0.672	3.143	1.052	1.579	7.310
Sig.	ns	*	ns	ns	**
CV (%)	16.6	10.4	19.8	8.4	3.3

Values are means of three replications; *ns*: non-significant; *: statistically significant at the 5% level; **: statistically significant at the 1% level; means with different letters are significantly different at $p < 0.05$ according to the Duncan's significant difference test.
Source: Authors' calculations.

Regarding cabbage head diameter measured at 40, 50, and 56 days after planting, the results indicated variation among treatments (Table 5). Throughout the growth period, treatment T5 consistently produced the largest head diameters, measuring 10.93 cm, 17.20 cm, and 19.03 cm at 40, 50, and 56 days, respectively. Although treatment T2 recorded the smallest diameter at day 40 (7.47 cm), it showed substantial growth and reached the second-largest diameter (18.20 cm) by harvest (56 days). One-way ANOVA analysis revealed no significant differences among treatments at 40 and 50 days; however, significant differences were detected at harvest (56 days after planting).

Vermicompost (VC) and vermicompost tea (VCT) are biofertilizess considered valuable tools in sustainable agriculture. Previous studies have shown that application of VC and VCT had positive effects on the growth and yield parameters of crops (Luu et al., 2023a; Oyege and Bhaskar, 2025), soil properties, soil microbes, and the environment (Mohite et al., 2024; Yatoo et al., 2024; Oyege and Bhaskar, 2024).

In particular, the use of sole VCT or a combination of VCT and VC in agricultural cultivation has significantly promoted crop growth. Research by Yatoo et al. (2024) indicated that VC or VCT, applied alone or in combination, stimulated the height, length, number of branches, and leaf number of tomato plants. The tomato plants treated with VCT had a height of 57.80 cm; those in the VC treatment reached 68.82 cm; while the plants that received both VCT and VC grew to 74.12 cm. In contrast, the control group, which did not receive any VCT or VC, reached only 51.18 cm. The same tendency was recorded in the number of branches per tomato plant, with the highest and lowest numbers recorded in the VCT combined with VC treatment and the control, respectively (Yatoo et al., 2024).

Similarly, Oyege and Bhaskar (2025) conducted a study to evaluate the effects of VCT at varying concentrations (10%, 20%, and 40%), both individually and in combination with VC, applied at a rate of 2.47 t ha^{-1}. The results showed that treatments of VCT application alone and in combination with VC significantly increased the height of maize plants during all growth periods. Additionally, treating maize plants with 10% VCT resulted in greater height compared to treatments using 20% VCT and 40% VCT. Moreover, when 20% VCT and 40% VCT were combined with VC, the maize plants displayed better height performance than when these concentrations of VCT were applied individually (Oyege and Bhaskar, 2025).

The present observations confirm the findings of previous studies, demonstrating the beneficial effects of VC and VCT supplementation. In general, during the early stage of the growth period (20 days), plant growth performance – measured by height, foliage diameter, stem diameter, and number of leaves – was generally significantly higher in the VCT and VCT residue treatments compared to the 100% inorganic fertiliser treatment. In the later stages, only plant height and stem diameter in the VCT and VCT residue treatments were slightly improved compared to those in the 100% inorganic fertiliser treatment (T1). One plausible explanation in this case might be that in the later stages (from 30 days onward), cabbage plants concentrate nutrients on forming and developing the cabbage head (Duarte et al., 2019), so differences in growth parameters among treatments gradually narrowed. Additionally, at the time of harvest (56 days), the diameter of the cabbage head – a key factor directly linked to individual yield – was greater in the treatment combining VCT 1:5 with VCT residue (T5) and in the treatment combining VCT 1:10 with VCT residue (T6). These results were improved compared to the treatments that used only VCT at the respective concentrations (Table 5).

The findings of this study showed that the application of VCT in combination with VCT residue (the solid material remaining after producing VCT from original vermicompost material) resulted in improved growth performance. This aligns with the findings of Oyege and Bhaskar (2025), who demonstrated that VCT combined with VC stimulated maize growth more than VCT alone. These results suggest that the applications of VCT and VCT residue can enhance nutrient uptake, provide growth-promoting hormones, and improve soil properties, leading to increased plant growth performance (Che Sulaiman and Mohamad, 2020; Alkobaisy et al., 2021; Mohite et al., 2024; Amante, 2024).

Effects of vermicompost tea and vermicompost tea residue on the yield parameters of white cabbage head

The results of this study revealed large variations in the average individual weight of cabbage heads at harvest and the total plot yield of white cabbage across the different treatments (Table 6, Figure 1). The average weight of a single cabbage head in treatment T5 (VCT 1:5 + VCT residue + 50% inorganic fertiliser) was the highest, with a mean of 1.24 kg, representing a 49.4% increase compared to the treatment using only inorganic fertiliser (T1). Following T5, treatment T6 (VCT 1:10 + VCT residue + 50% inorganic fertiliser) had a mean cabbage head weight of 1.01 kg. Consequently, one-way ANOVA analysis indicated significant differences in individual cabbage head weight among treatments. Notably, the average individual cabbage head weight in treatment T5 was significantly higher compared to all other treatments (Table 6).

Table 6. Effects of vermicompost tea and vermicompost residue on the individual weight and plot yield of cabbage plants.

Treatments	The individual weight and plot yield of cabbage head (fresh weight)	
	Individual weight (kg cabbage^{-1})	Plot yield of 3 m^2 (kg)
T1 (control)	0.83 ± 0.02cd	7.00 ± 0.15cd
T2	0.96 ± 0.02b	7.50 ± 0.17c
T3	0.81 ± 0.06d	6.90 ± 0.10d
T4	0.79 ± 0.05d	6.80 ± 0.12d
T5	1.24 ± 0.05a	8.73 ± 0.29a
T6	1.01 ± 0.03b	8.00 ± 0.12b
T7	0.94 ± 0.03bc	7.20 ± 0.12cd
$F_{(6,14)}$	16.699	18.279
Sig.	**	**
CV (%)	6.7	3.8

Values are means of three replications; **: statistically significant at the 1% level; means with different letters are significantly different at $p < 0.05$ according to the Duncan's significant difference test.
Source: Authors' calculations.

In terms of plot yield, the highest total cabbage yield, 8.73 kg per 3 m² plot, was recorded in treatment T5 (VCT 1:5 + VCT residue + 50% inorganic fertiliser), while the lowest yield, 6.80 kg per 3 m² plot, was observed in treatment T4 (VCT 1:15 + 50% inorganic fertiliser). In treatment T1 (inorganic fertiliser only), the cabbage yield reached 7.00 kg per 3 m^2 plot, which was 1.73 kg lower than the plot yield in treatment T5. Consequently, the yield in treatment T5 was 24.7% higher compared to treatment T1 (inorganic fertiliser only). Meanwhile, the cabbage yield in treatment T2 (applications of VCT 1:5 and 50% inorganic fertiliser) increased by only 7.1% compared to treatment T1. These results indicated the effectiveness of utilising by-products (i.e., VCT residue) in agriculture (Table 6, Figure 1). Statistical analysis confirmed that plot yields in treatments T5 and T6 were significantly higher than those in the other treatments, including the inorganic fertiliser-only treatment (T1).

Figure 1. Sizes of cabbage head in different treatments.
T1 (control): 100% inorganic fertilisers; T2: VCT 1:5 + 50% inorganic fertilisers; T3: VCT 1:10 + 50% inorganic fertilisers; T4: VCT 1:15 + 50% inorganic fertilisers; T5: VCT 1:5 + VCT residue + 50% inorganic fertilisers; T6: VCT 1:10 + VCT residue + 50% inorganic fertilisers; T7: VCT 1:15 + VCT residue + 50% inorganic fertilisers. Source: Authors' photograph.

In terms of potential use of VCT alone or combined with VC to boost crop productivity, previous studies have demonstrated that VCT supplementation increased the yield of pak choi (Paint et al., 2012), broccoli (Alkobaisy et al., 2021), sugar beet (Ghaffari et al., 2022), Chinese kale (Luu et al., 2023a), tomato (Yatoo et al., 2024), and maize (Oyege and Bhaskar, 2025).

In the present study, the mean individual fresh weight of cabbage head in the VCT 1:5 treatment (20% VCT) was higher than that in the treatments of VCT 1:10 and VCT 1:15 (10% VCT and 6.7% VCT, respectively). In addition, the combination of VCT and VCT residue significantly improved the individual weight of the cabbage head. Specifically, the average individual weight of cabbage head in the treatment of VCT 1:5 combined with VCT residue (T5) achieved 1.24 kg, compared to only 0.96 kg per cabbage head in the VCT 1:5 treatment (T2), an increase of 29.2%. Similarly, increases of 24.7% and 19.0% were found in VCT 1:10 combined with VCT residue (T6) in comparison with VCT 1:10 alone (T3), and in VCT 1:15 combined with VCT residue (T7) compared with VCT 1:15 alone (T4), respectively.

A similar trend was also observed in plot yield (Table 6; Figure 1). Notably, the mean individual weight and 3-m² plot yield of cabbage heads in treatments T5 (VCT 1:5 + VCT residue) and T6 (VCT 1:10 + VCT residue) were significantly higher than in the other treatments, including the control (inorganic fertiliser only). The findings of this study highlighted the potential for partially replacing inorganic fertilisers with organic fertilisers. In this case, using VCT alone or in combination with VCT residue can reduce the use of inorganic fertiliser in the top dressing period by 50% without affecting crop productivity. Specifically, using VCT 1:5 (20% VCT) with 50% inorganic fertilisers (T2) increased individual weight and plot yield of 3 m^2 by 15.7% and 7.1%, respectively, compared to the control (100% inorganic fertilisers). Furthermore, 20% VCT combined with VCT residue (T5) improved individual weight and 3-m^2 plot yield by 49.3% and 24.7%, respectively, compared to the control. In contrast, treating VCT 1:10 (10% VCT) and 50% inorganic fertilisers (T3) decreased plot yield by 1.4% in comparison to the control, but in combination with VCT residue, plot yield increased by 14.3% compared to the control. This confirmed the results of a previous study, which found that integrating liquid fertiliser and solid organic fertiliser improved crop yield compared to using liquid fertiliser alone (Hatibie and Garantjang, 2022). The reason for this is that the combined application helps improve soil quality, enhance microbial activity, and retain nutrients for longer, thereby increasing nutrient uptake efficiency and crop growth compared to using liquid fertiliser alone (Luu et al., 2023b).

The results of this study were consistent with the findings of previous studies and confirmed the positive effects of VCT and VCT residue on crop yield. For example, Alkobaisy et al. (2021) demonstrated that spraying 1% VCT (used as irrigation water) combined with 50% inorganic fertilisers improved the weight of the main broccoli flower disc by 30.6% compared to the 100% inorganic fertiliser treatment. Moreover, treating VCT with VC was even more effective, resulting in a 35.4% increase in broccoli flower disc weight in comparison to the 100% inorganic fertiliser treatment (Alkobaisy et al., 2021). Meanwhile, Pant et al. (2012) demonstrated that 10% VCT supplementation had better effects on the yield of pak choi (*Brassica rapa*) than 5% VCT application under both greenhouse and field conditions.

To sum up, VCT and VCT residue contribute to improved growth and yield in various crops. This highlights that VCT and VCT residue contain high content of macronutrients (N, P, K), micronutrients, beneficial microorganisms, and plant growth regulators (Pant et al., 2012; Che Sulaiman and Mohamad, 2020; Alkobaisy et al., 2021; Arosha and Sarvananda, 2022). Moreover, VCT residue, the solid by-product remaining after the production of VCT from the original vermicompost material, possesses slow-release properties and a high organic content, allowing crops to absorb nutrients more effectively and enhancing soil properties (Oyege and Bhaskar, 2023). Consequently, adding VCT in combination with VCT residue in agricultural cultivation effectively promoted the growth and yield of crops. It is clear that the effects of VCT depend on the type of crops, original vermicompost material, the method of preparing VCT, and the applied method (Pant et al., 2012; Alkobaisy et al., 2021; Oyege and Bhaskar, 2024; Oyege and Bhaskar, 2025). However, this study has shown beneficial effects on cabbage yield when applied under appropriate conditions.

Conclusion

Vermicompost tea (VCT) and VCT residue had positive effects on the growth and yield of white cabbage. VCT 1:5 with 50% inorganic fertilisers resulted in significant improvements in the cabbage head diameter and average individual weight at 56 days in comparison to the treatment with inorganic fertilisers only. In contrast, the treatments of VCT 1:10 and VCT 1:15 did not show better effects on cabbage growth and yield than the inorganic fertiliser treatment alone. Noticeably, significant increases in plot yield of 24.7% and 14.3% were recorded in the treatments of VCT 1:5 in combination with VCT residue + 50% inorganic fertilizsers (T5) and VCT 1:10 in combination with VCT residue + 50% inorganic fertilisers (T6), respectively, compared to the treatment with 100% inorganic fertilisers (T1). These results revealed that VCT combined with VCT residue can replace up to 50% of inorganic fertilisers in cabbage cultivation. Consequently, the findings of this study demonstrate that a combination of VCT and VCT residue is highly effective in improving crop productivity and highlights the potential for recycling waste materials in sustainable agriculture.

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UTICAJ TEČNOG EKSTRAKTA GLISTENJAKA I NJEGOVOG OSTATKA NA RAST I PRINOS KUPUSA

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R e z i m e

Kupus (*Brassica oleracea* var. *capitata*) jedna je od najstarijih poznatih povrtarskih kultura i često se gaji širom sveta. Tečni ekstrakt glistenjaka (engl. *vermicompost tea – VCT*) smatra se biođubrivom i koristi se u održivoj poljoprivredi za povećanje prinosa useva i poboljšanje svojstava zemljišta. Ovo istraživanje sprovedeno je sa ciljem procene efikasnosti tečnog ekstrakta glistenjaka i ostatka tečnog ekstrakta glistenjaka (čvrstog materijala koji ostaje nakon proizvodnje tečnog glistenjaka), kao i njihove sposobnosti da delimično zamene mineralna đubriva u pogledu rasta i prinosa kupusa u poljskim uslovima. Rezultati su pokazali da primena tečnog ekstrakta glistenjaka i ostatka tečnog ekstrakta glistenjaka u odnosu 1:5 u kombinaciji sa 50% mineralnim đubrivom značajno povećava prečnik glavice kupusa i njenu prosečnu pojedinačnu masu pri berbi u poređenju sa tretmanom gde su primenjena samo mineralna đubriva. Posebno je uočeno da je primena tečnog ekstrakta glistenjaka u kombinaciji 1:5 sa ostatkom tečnog ekstrakta glistenjaka + 50% mineralnih đubriva, kao i tečnog ekstrakta glistenjaka u kombinaciji 1:10 sa ostatkom tečnog ekstrakta glistenjaka + 50% mineralnih đubriva, pokazala najbolje rezultate među tretmanima, sa značajnim povećanjem prinosa na parceli od 3 m² za 24,7%, odnosno 14,3% u poređenju sa tretmanom gde su primenjena samo mineralna đubriva. Ovi rezultati pokazuju da tečni ekstrakt glistenjaka u kombinaciji sa ostatkom tečnog ekstrakta glistenjaka može zameniti značajan deo mineralnih đubriva u uzgajanju kupusa, čime se smanjuje oslanjanje na ove neodržive proizvode, uz istovremeno recikliranje otpadnih materijala u održivoj poljoprivredi.

Ključne reči: *Brassica oleracea* var. *capitata*, kupus, organska đubriva, tečni ekstrakt glistenjaka, ostatak tečnog ekstrakta glistenjaka.

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