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EFFECTS OF DIFFERENT EARTHWORM EXTRACT CONCENTRATIONS ON THE GROWTH AND YIELD OF CHINESE CABBAGE (*Brassica pekinensis*) UNDER FIELD CONDITIONS

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Abstract – *The use of organic fertilizers has been increasingly promoted to enhance crop productivity while reducing the environmental impacts associated with excessive chemical fertilizer use. This study evaluated the effects of different concentrations of earthworm extract on the growth and yield of Chinese cabbage (Brassica pekinensis) under open-field conditions in Vinh Long Province, Vietnam, from July to October 2024. The experiment was conducted using a randomized complete block design with six treatments consisting of earthworm extract concentrations of 0, 20, 25, 30, 35, and 40 mL diluted in 20 L of water, with five replications. Earthworm extract was applied as a foliar spray at ten-day intervals throughout the crop cycle. Growth parameters, including plant height, leaf number, canopy width, and stem base diameter, were recorded at different growth stages, while biomass and yield were evaluated at harvest. The results showed that earthworm extract significantly enhanced plant growth and yield compared with the control treatment. The highest concentration (40 mL) produced the greatest plant biomass (290.1 g/plant) and the highest yield (32,757 kg/ha). These findings provide practical evidence for optimizing earthworm extract application to enhance yield and support sustainable Chinese cabbage production under field conditions.*

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I. INTRODUCTION

Chinese cabbage (*Brassica pekinensis*) is a valuable leafy crop in the genus *Brassica*, widely cultivated worldwide, with a strong concentration in Asian regions [1]. The annual production of Chinese cabbage in Asia exceeds 50 megatons, accounting for about 70% of the world's production [2]. Chinese cabbage plays an important role in the leafy vegetable sector thanks to its high yield and wide adaptability to diverse weather, climate, and soil conditions [3]. It provides essential vitamins and minerals beneficial to human health and contributes significantly to household income in vegetable-growing communities [4]. As living standards rise and vegetable options become more diverse, consumers are placing greater emphasis on the quality of vegetables, including Chinese cabbage [2]. However, the increasing demand for vegetables has led farmers to rely heavily on chemical fertilizers. Excessive use of synthetic fertilizers degrades soil structure, reduces long-term fertility, and increases the risk of nitrate accumulation in vegetables [5]. In recent years, sustainable agricultural practices have gained increasing attention, with the use of organic fertilizers recognized as an important approach to enhancing crop productivity, improving soil health and environmental quality, while reducing reliance on chemical fertilizers [6]. Earthworm extract (EE) is a product obtained by hydrolyzing fresh earthworms, containing soluble nutrients, humic substances, plant growth regulators, and beneficial microorganisms. It is widely used in agriculture because it promotes plant growth and development, increases crop yield and quality [7]. The coastal and alluvial soils of Vinh Long Province are increasingly affected by declining fertility and climate-related pressures such as salinity intrusion. The use of organic fertilizers helps stimulate soil microbial populations and activity, facilitates salt redistribution and transformation within the soil, and consequently lowers overall salinity levels [8]. Earthworm extract is considered a promising alternative to partially replace chemical fertilizers in local vegetable systems. This study aims to evaluate the effects of five different EE concentrations on the growth and yield of Chinese cabbage under open-field conditions. The findings are expected to provide scientific evidence for optimizing organic fertilizer use, improving crop productivity, and contributing to more sustainable vegetable production in the region.

II. LITERATURE REVIEW

Chinese cabbage, which originated in China, is gaining popularity among both growers and consumers due to its short growth cycle, ease of cultivation, distinctive taste, numerous health benefits, and appealing appearance [9, 10]. According to data reported by the United States Department of Agriculture (USDA) [11], Chinese cabbage contains approximately 5% dry matter and provides dietary fiber at around 10 g/kg. It is also a notable source of minerals, including potassium at about 2,520 mg/kg, calcium 1,050 mg/kg, magnesium 190 mg/kg, and sodium 650 mg/kg on a fresh weight basis. This crop is well adapted to tropical climatic conditions; however, its yield and quality are strongly influenced by nutrient management and soil cultivation practices. In the context of rising demand for safe vegetables, reducing dependence on chemical fertilizers has become an essential trend toward sustainable agricultural production.

Earthworm extract is considered a promising organic alternative to chemical fertilizers, as the extract improves soil fertility, enhances plant growth, and strengthens the natural resistance of crops to pests and diseases [12]. Earthworm extract provides readily available nutrients and beneficial microorganisms that can be quickly absorbed and utilized by plants [13]. Although the exact mechanisms are not fully clarified, EE is thought to supply readily available minerals, organic acids, and water-soluble growth regulators that enhance early root formation and overall plant development when applied either to foliage or soil [14]. Additionally, its beneficial microbial communities can improve nutrient uptake and promote plant vigor while contributing to enhanced resistance against plant diseases [15].

Numerous studies conducted both in Vietnam and internationally have demonstrated that the application of EE at appropriate concentrations can improve yield and quality in *Brassica* crops such as mustard greens, bok choy, and cabbage [16–18]. However, the effectiveness of EE varies significantly depending on application rates, timing, and specific crop species. Evaluated foliar fertilizers extracted from earthworm compost at concentrations of 10, 20, and 30 mL per 8 L of water applied to *Brassica* integrifolia, resulting in a 14–39% yield increase compared to the untreated control [16]. In addition, the study demonstrated that applying earthworm-based fertilizer at 15, 30, and 45 mL per 8 L of water to tomato plants enhanced growth and increased fruit yield by 10–27%. In 2021, Phan Hoang An et al. [17] conducted field experiments under conventional cultivation systems by applying supplementary EE to *Basella alba*, *Brassica* spp., and *Ipomoea aquatica*. The results showed that the yields of these vegetables increased by 2.58-, 2.39-, and 1.62-fold, respectively, compared with the control treatment without EE application. Pant et al. [18] reported that weekly applications of EE at 200 mL per plant significantly enhanced the growth of pak choi (*Brassica rapa* Chinensis group), with notable increases in shoot biomass, root development, and nutrient uptake compared with the control treatment without EE. Oyege et al. [13] evaluated EE application in sweet corn under field conditions and found that the EE20 treatment achieved the highest cob yield of 6.00

t/ha, which was more than eight times greater than the unfertilized control (0.72 t/ha).

For Chinese cabbage (*Brassica pekinensis*), research evaluating the effects of EE under open-field conditions remains limited, particularly in the agro-ecological context of the Mekong Delta region. Therefore, assessing the impact of different EE concentrations on the growth and yield of Chinese cabbage is essential. The findings will provide a scientific basis for selecting efficient organic fertilization practices, contributing to safe vegetable production while enhancing economic value and sustainability in cultivation.

III. RESEARCH METHODS

A. Research materials

The experiment was carried out at the Production Area of the School of Agriculture and Aquaculture, Tra Vinh University, located in Ward 5, Tra Vinh City, Tra Vinh Province (currently Hoa Thuan Ward, Vinh Long Province), from July to October 2024.

Variety Chinese cabbage 'Hello' supplied by Trang Nong Trading Co, Ltd. This variety is easy to cultivate and manage and is well adapted to the climatic conditions in Vietnam.

Earthworm extract produced by Phuoc Hiep Earthworm Farm, located at Ho Chi Minh City. The nutrient composition of the EE used in this study was analyzed by the Center for Analytical Services and Experimentation Ho Chi Minh City (CASE, Vietnam). The results indicated that the extract contained N (4.88%), P (2.07%), K (2.61%), Fe (808 mg/kg), Cu (21.2 mg/kg), Zn (13.1 mg/kg), Mg (0.12%), and Mn (0.13%). In addition, the total amino acid content reached 2.29 g/100 g.

B. Research methods

Experimental procedures

The experiment was conducted under average temperatures of 26–27^{o}C, with annual rainfall of 1,400–1,600 mm and relative humidity of about 84%. The soil consists mainly of alluvial soil with moderate fertility.

Chinese cabbage seeds were pre-germinated in foam seedling trays (40 cm × 20 cm, 84 cells per tray) using a commercial organic growing substrate (100% organic matter consisting of cow manure, goat manure, rice husk ash, and coir fiber). The substrate moisture content was maintained at 65–75%. Seedlings with approximately four true leaves (around two weeks after sowing) were considered suitable for transplanting into the prepared field plots. A spacing of 15 × 20 cm was applied, corresponding to a planting density of approximately 33 plants per square meter. Each experimental plot had an area of 10 m^2.

Before transplanting, the soil at the experimental site was plowed, exposed to sunlight for 7–10 days, treated for pest control, and formed into beds, followed by the application of basal fertilizer. The fertilizer application regime used in this study was based on the cultivation guidelines for Chinese cabbage described by Tran Thi Ba et al. [19], with specific fertilizer rates and timing provided in Table 1.

Table 1: Fertilizer rates and application schedule for Chinese cabbage

Days after sowing	Application method	Fertilizer rates			
		Urea (kg/ha)	NPK (16-16-8) (kg/ha)	Fish fertilizer (or bio-organic NPK) (L/ha)	Microbial organic fertilizer (kg/ha)
0 (basal)	Broadcasting	-	200	-	2,000
7	Watering	10	-	-	-
14	Broadcasting	10	100	-	-
20	Watering	30	-	-	-
23	Watering	-	-	5	-
26	Watering			5	-
Total		50	300	10	2,000

Experimental design and treatments

The experiment was arranged in a randomized complete block design (RCBD) with six treatments, including control treatment (CT), treatment 1 (T1), treatment 2 (T2), treatment 3 (T3), treatment 4 (T4), and treatment 5 (T5), and five replications, three plants per replicate (Table 2). The experimental layout is presented in Table 3 [20].

C. Data collection

Three plants per replication per treatment were randomly selected to monitor and collect data on

Table 2: Earthworm extract concentrations and foliar application schedule used in the experiment

Treatment	Earthworm extract concentration and application frequency
CT	0 mL EE + 20 L water, sprayed every 10 days
T1	20 mL EE + 20 L water, sprayed every 10 days
T2	25 mL EE + 20 L water, sprayed every 10 days
T3	30 mL EE + 20 L water, sprayed every 10 days
T4	35 mL EE+ 20 L water, sprayed every 10 days
T5	40 mL EE + 20 L water, sprayed every 10 days

Table 3: Experimental layout in a randomized complete block design

Block 1	Block 2	Block 3	Block 4	Block 5
CT	T3	T1	T4	T2
T1	T4	T2	T5	T3
T2	T5	T3	CT	T4
T3	CT	T4	T1	T5
T4	T1	T5	T2	CT
T5	T2	CT	T3	T1

growth parameters and individual yield throughout the experimental period. Chinese cabbage was harvested at 37 days after transplanting (DAT).

The monitored parameters included leaf number (leaves plant^{-1}), plant height (cm), stem base diameter (cm), and canopy width (cm). Measurements were initiated approximately seven days after transplanting, once the plants had established and recovered from transplanting stress, and were subsequently recorded at 4-day intervals until harvest. Plant height was measured from the soil surface to the apical growing point of the main stem. At harvest, fresh biomass (g plant^{-1}) was determined by weighing the whole plant after cutting at the stem base. Besides, leaf length (cm) and leaf width (cm) were measured on a representative healthy leaf selected from each plant.

Sensory quality of Chinese cabbage was assessed based on bitterness and crispness using a structured scoring method. Bitterness was evaluated on a five-point scale (1 = bitter to 5 = very sweet), while crispness was rated on a two-point scale (1 = tough, 2 = crisp). The evaluation was conducted under field conditions by five trained panelists using a randomized, blind procedure. Final scores for each treatment were calculated as the mean of all panelists. This assessment was intended as a preliminary evaluation to provide an initial indication of sensory quality attributes. Theoretical yield was estimated based on plant density and average plant weight using Equation (1), while actual yield (kg/m^2) was calculated by weighing the total mass of Chinese cabbage plants within a 1 m^2 area following Equation (2).

D. Data analysis

Data were processed using Microsoft Excel and analyzed by analysis of variance (ANOVA) and Duncan's multiple range test at the 1% and 5% significance levels using SPSS version 22.0 [21].

IV. RESULTS AND DISCUSSION

A. Effect of earthworm extract on the height of Chinese cabbage

The results presented in Table 4 and Figure 1 show that the height of Chinese cabbage increased steadily over time across all treatments. At 7 DAT, plant height in the control (CT) was 10.32 cm, whereas treated plants ranged from 11.39 cm (T1) to 12.66 cm (T4). A similar trend was observed at 11 DAT, where plant height increased from 12.73 cm in CT to 16.06 cm in T5, indicating a clear early growth-promoting effect of EE.

From 15 DAT onwards, the differences among treatments became more distinct. At 15 DAT, CT reached 13.79 cm, while T3, T4, and T5 recorded 17.39, 17.33, and 18.39 cm, respectively. By 19 DAT, plant height in T5 (21.13 cm) exceeded that of CT (14.33 cm) by nearly 7 cm. This gap continued at 23 DAT, with T5 reaching 21.92 cm compared to 14.39 cm in the control.

During the later stages of development, the superiority of higher treatment levels became more evident. At 27 DAT, plant height ranged from 15.66 cm (CT) to 22.73 cm (T5). By 31 DAT, T5 reached 23.39 cm, while CT remained at 16.26 cm. At the final observation, 35 DAT, T5 achieved the maximum height of 25.66 cm, compared to 17.59 cm in the control, representing a difference of more than 8 cm. Treatments T3–T5 consistently outperformed T1–T2 across all observation periods, indicating a strong positive response to increasing concentrations of EE. This finding is in agreement with Luu Thi Thuy Hai et al. [22], who demonstrated a positive correlation between EE application rates and plant height, with the highest value reaching 28.6 cm at 37 DAT. Treatments T3–T5 demonstrated superior performance compared to T1–T2, showing a positive growth response with increasing concentrations of EE. This trend is consistent with the findings of Tran Thi Truong Linh et al. [16], who reported that increasing the application rate of vermicompost fertilizer enhanced plant height in *Brassicaceae* crops.

The growth-promoting effects may be attributed to readily available nutrients and bioactive compounds such as humic substances, auxins, and gibberellins present in EE [23]. These findings are consistent with a previous study, which reported an 18% increase in height in leafy vegetables treated with vermicompost [24].

B. Investigation of the effect of earthworm extract on leaf emergence in Chinese cabbage

Leaves are the primary organs responsible for photosynthesis and the production of organic compounds essential for plant growth. Therefore, the number and size of leaves directly indicate the plant's growth status at a given stage. A well-developed leaf canopy typically enhances photosynthetic activity, resulting in greater organic matter accumulation and improved yield. This observation aligns with Ta Thu Cuc [25], who stated that photosynthesis accounts for 90–95% of the plant's dry matter formation, meaning that an increase in leaf number is positively associated with higher yield.

The results in Table 5 show that leaf number increased steadily over time in all treatments. At 7 DAT, the CT had 5.22 leaves, while treated plants ranged from 5.46 leaves (T1) to 6.56 leaves (T5). This trend remained at 11 DAT, where T5 reached 7.26 leaves compared to 6.13 leaves in CT, indicating an early positive effect of EE. From 15 to 23 DAT, differences became more evident. At 15 DAT, CT recorded 7.46 leaves, whereas T4 and T5 reached 9.06 and 8.86 leaves. By 19 DAT, T4 and T5 increased to 10.73 and 10.66 leaves, compared to 8.86 leaves in CT. At 23 DAT, treated plants (T3–T5) ranged from 11.25 to 11.86 leaves, while CT remained at 9.93 leaves. At later growth stages, T5 consistently showed the highest values. At 27 and 31 DAT, T5 reached 12.59 and 14.32 leaves, respectively, compared to 10.26 and 11.93 leaves in CT. At 35 DAT, T5 recorded the maximum leaf number (15.99 leaves), while CT had 12.72 leaves.

Such improvements may be attributed to the availability of essential nutrients (especially nitrogen and potassium) along with humic substances, enzymes, and beneficial microorganisms in EE, which support photosynthesis, cell division, and leaf tissue expansion [26]. These factors contribute to a larger photosynthetic surface area, thereby potentially improving biomass accumulation and yield performance.

Overall, the application of EE positively affected leaf development in Chinese cabbage, with T5 being the most effective treatment, suggesting its potential applicability in commercial vegetable production.

C. Effect of earthworm extract on the canopy width of Chinese cabbage

The canopy diameter is an important agronomic indicator, as it determines appropriate planting density to optimize light interception and maximize photosynthetic efficiency [27].

The results in Table 6 and Figure 2 show that canopy width increased steadily over time in all treatments. At 7 DAT, canopy width in the CT was 15.66 cm, while treated plants ranged from 16.59 cm (T1) to 19.13 cm (T5). A similar trend was observed at 11 DAT, with T5 reaching 23.66 cm compared to 18.19 cm in CT. From 15 to 23 DAT, treatment effects became more pronounced. At 15 DAT, canopy width increased from 19.73 cm in CT to 26.66 cm in T5. By 19 DAT, T4 and T5 reached 28.13 and 28.59 cm, respectively, while CT remained at 20.86 cm.

Table 4: Investigation of the effect of earthworm extract on the height growth of Chinese cabbage (cm/plant)

Treatment	Chinese cabbage plant height at different days after transplanting							
	7 DAT	11 DAT	15 DAT	19 DAT	23 DAT	27 DAT	31 DAT	35 DAT
CT	10.32[b]	12.73[b]	13.79[c]	14.33[c]	14.39[d]	15.66[d]	16.26[d]	17.59[d]
T1	11.39[ab]	14.19[ab]	15.72[bc]	16.46[bc]	16.86[cd]	17.19[cd]	17.86[bcd]	19.33[cd]
T2	12.51[a]	14.33[ab]	16.26[bc]	17.39[b]	17.33[bcd]	17.99[bcd]	18.66[bcd]	20.46[bcd]
T3	12.46[a]	15.19[a]	17.39[ab]	18.59[ab]	19.39[abc]	19.93[bc]	20.52[abc]	22.32[abc]
T4	12.66[a]	14.99[a]	17.33[ab]	19.19[ab]	19.86[ab]	20.59[ab]	21.53[ab]	23.59[ab]
T5	12.35[a]	16.06[a]	18.39[a]	21.13[a]	21.92[a]	22.73[a]	23.39[a]	25.66[a]
Significance level	**	*	**	**	**	**	**	**
CV%	9.8	11.2	14.0	15.9	16.1	15.8	15.9	16.2

(A) 11 DAT (B) 19 DAT

Fig. 1: Plant height of Chinese cabbage at different growth stages

At 23 DAT, T5 recorded 28.86 cm compared to 21.24 cm in the control. Higher treatments maintained clear superiority. At 27 DAT, canopy width ranged from 21.86 cm (CT) to 29.39 cm (T5). At 31 DAT, T5 reached 29.99 cm, while CT was 22.13 cm. By 35 DAT, T5 achieved the maximum canopy width (31.73 cm), compared to 23.06 cm in CT, showing a difference of nearly 9 cm.

This trend indicates a positive response of canopy development to increasing EE concentrations and is consistent with previous findings. Son Thi Thanh Nga et al. [28] reported a proportional increase in plant growth with higher vermicompost extract levels, with the highest treatment (60 mL/20 L) achieving a maximum canopy diameter of 54.6 cm at 34 DAT. Similarly, Luu Thi Thuy Hai et al. [22] demonstrated that canopy diameter increased with higher vermicompost application rates, reaching 33.3 cm at 37 days after planting. In addition, the study by Pant et al. [18] demonstrated that EE promoted shoot and leaf development and enhanced plant growth, mineral nutrient accumulation, phytonutrient content, and antioxidant activity in pak choi.

D. Effect of earthworm extract on the stem base diameter of Chinese cabbage

The results in Table 7 show that stem base diameter increased gradually over time in all treatments. At 7 DAT, the CT recorded 0.35 cm, while treated plants ranged from 0.41 cm (T1) to 0.49 cm (T4). A similar trend was observed at 11 DAT, with values increasing from 0.42 cm in CT to 0.52 cm in T4. From 15 to 23 DAT, treatment effects became more evident. At 15 DAT, stem diameter increased from 0.52 cm in CT to 0.67 cm in T4. By 19 DAT, T5 reached 0.77 cm compared to 0.55 cm in CT. T5 recorded 0.81 cm, while CT remained at 0.58 cm at 23 DAT, indicating a clear difference among treatments. At later stages, higher treatments continued to show superior performance. Stem diameter ranged from 0.66 cm (CT) to 0.89 cm (T5). A similar tendency persisted 31 DAT, T5 reached 0.96 cm compared to 0.73 cm in CT. By 35 DAT, T5 achieved the maximum diameter (1.01 cm), whereas CT recorded only 0.77 cm. These improvements are consistent with earlier findings showing that vermicompost or its liquid extract enhances stem girth, shoot vigor, and structural strength in various vegetable crops due to increased nutrient uptake, hormonal activity, and beneficial microbial interactions [18].

Enhanced stem base diameter reflects improved biomass accumulation and greater vas-

Table 5: Effect of earthworm extract concentrations on leaf number of Chinese cabbage (leaves/plant)

Treatment	Leaf number of Chinese cabbage at various days after transplanting							
	7 DAT	11 DAT	15 DAT	19 DAT	23 DAT	27 DAT	31 DAT	35 DAT
CT	5.22^{c}	6.13	7.46^{b}	8.86^{b}	9.93	10.26^{b}	11.93^{b}	12.72^{c}
T1	5.46^{bc}	6.79	8.33^{ab}	9.53^{ab}	10.99	11.73^{ab}	13.39^{ab}	14.19^{b}
T2	5.68^{b}	6.86	8.53^{a}	10.13^{ab}	11.13	11.53^{ab}	12.93^{ab}	13.93^{bc}
T3	5.74^{b}	6.99	8.86^{a}	10.19^{ab}	11.25	11.99^{a}	13.06^{ab}	14.73^{ab}
T4	6.24^{a}	7.13	9.06^{a}	10.73^{a}	11.86	12.52^{a}	13.93^{a}	15.26^{ab}
T5	6.56^{a}	7.26	8.86^{a}	10.66^{a}	11.86	12.59^{a}	14.32^{a}	15.99^{a}
Significance level	**	ns	*	*	ns	*	*	*
CV%	9.1	11.7	10.2	10.9	10.8	11.0	9.7	9.6

Table 6: Effect of earthworm extract on canopy width growth of Chinese cabbage (cm/plant)

Treatment	Canopy width of Chinese cabbage on different days after transplanting							
	7 DAT	11 DAT	15 DAT	19 DAT	23 DAT	27 DAT	31 DAT	35 DAT
CT	15.66	18.19	19.73^{c}	20.86^{c}	21.24^{c}	21.86^{c}	22.13^{c}	23.06^{c}
T1	16.59	20.39	22.39^{bc}	23.33^{bc}	23.66^{bc}	24.26^{bc}	24.66^{bc}	25.39^{c}
T2	18.26	22.19	24.56^{ab}	26.13^{ab}	26.32^{ab}	26.73^{ab}	27.33^{ab}	28.48^{b}
T3	18.39	22.46	25.53^{ab}	26.92^{ab}	27.33^{a}	27.66^{ab}	28.46^{a}	29.53^{ab}
T4	18.99	23.19	26.53^{a}	28.13^{a}	28.39^{a}	28.79^{a}	29.39^{a}	30.79^{ab}
T5	19.13	23.66	26.66^{a}	28.59^{a}	28.86^{a}	29.39^{a}	29.99^{a}	31.73^{a}
Significance level	ns	ns	*	*	*	*	**	**
CV%	12.4	15	14.6	14.5	13.9	13.3	13.2	12.8

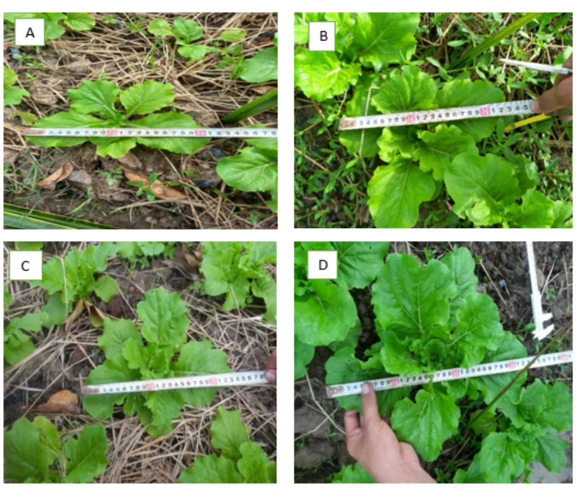

Fig. 2: Canopy width of Chinese cabbage at different growth stages: (A) 11 DAT, (B) 15 DAT, (C) 19 DAT, and (D) 35 DAT

cular tissue development, supporting more efficient translocation of water and nutrients, which are essential for subsequent canopy expansion and yield formation [14]. Therefore, T5 can be identified as the optimal treatment for improving stem development and promoting stronger plant growth in Chinese cabbage.

E. Assessment of the effects of earthworm extract on post-harvest biomass, leaf length, and leaf width

Figure 3 shows that both leaf length and leaf width increased progressively with higher concentrations of EE. In the CT, leaf length and width were 16.7 cm and 11.1 cm, respectively. These values increased gradually across treatments, reaching 23.7 cm (length) and 14.3 cm (width) in T5. A consistent upward trend was observed from T1 to T5. Leaf length increased from 17.7 cm (T1) to 21.1 cm (T4), while leaf width rose from 11.9 cm to 13.7 cm over the same treatments. This indicates that EE positively influenced leaf expansion. Higher treatments (T4–T5) showed more pronounced effects compared to lower levels. The difference between CT and T5 was approximately 7.0 cm for leaf length and 3.2 cm for leaf width, highlighting a strong response to increasing extract concentration.

These improvements agree with previous findings showing that vermicompost and its aque-

Table 7: Effect of earthworm extract on stem base diameter of Chinese cabbage (cm/plant)

Treatment	Stem base diameter of Chinese cabbage at different							
	7 DAT	11 DAT	15 DAT	19 DAT	23 DAT	27 DAT	31 DAT	35 DAT
CT	0.35^{b}	0.42	0.52	0.55^{b}	0.58^{c}	0.66^{d}	0.73^{c}	0.77^{d}
T1	0.41^{ab}	0.47	0.57	0.65^{ab}	0.67^{bc}	0.74^{cd}	0.82^{bc}	0.85^{cd}
T2	0.47^{a}	0.51	0.65	0.70^{a}	0.71^{ab}	0.78^{bc}	0.83^{b}	0.87^{bc}
T3	0.46^{a}	0.50	0.62	0.69^{ab}	0.73^{ab}	0.81^{abc}	0.88^{ab}	0.92^{abc}
T4	0.49^{a}	0.52	0.67	0.74^{a}	0.79^{ab}	0.86^{ab}	0.91^{ab}	0.96^{ab}
T5	0.46^{a}	0.51	0.65	0.77^{a}	0.81^{a}	0.89^{a}	0.96^{a}	1.01^{a}
Significance level	*	ns	ns	*	**	**	**	**
CV%	17.3	16.2	17.9	13.2	15.8	13.0	11.7	11.3

ous extracts stimulate leaf growth by improving nutrient uptake, enhancing chlorophyll content, and supplying humic substances and bioactive compounds that promote cell division and elongation [18]. As leaf dimensions determine the total photosynthetic surface area, such increases contribute directly to enhanced biomass production and yield potential [29].

Therefore, T5 was identified as the most effective treatment for maximizing post-harvest leaf size of Chinese cabbage, confirming the superior efficacy of higher EE concentrations in promoting leaf morphological development.

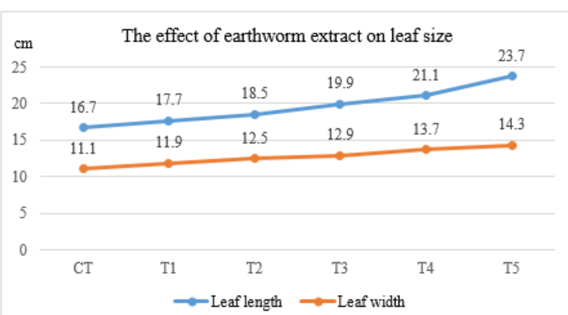

Fig. 3: Leaf dimensions after harvest

Plant biomass is genetically determined; however, its expression is strongly influenced by environmental and nutritional factors, particularly nutrient availability during early developmental stages [30]. Figure 4 shows that post-harvest biomass of Chinese cabbage increased substantially under EE treatments. The highest biomass was recorded in T5, reaching 290.1 g/plant for total biomass and 255.9 g/plant for edible biomass, compared to only 122.3 g/plant and 95.7 g/-plant in the CT, respectively. Treatments T3 and T4 also showed considerable improvements (approximately 218–241 g/plant), confirming the strong effect of EE on biomass accumulation. This suggests that EE may provide nutrients in a more readily available form, facilitating faster uptake and utilization by plants, thereby promoting more efficient biomass accumulation compared to conventional vermicompost. Earthworm extract is known to contain plant growth-promoting compounds such as humic substances, auxins, cytokinins, enzymes, and beneficial microorganisms that stimulate vigorous root growth, nutrient absorption, and biomass production [14].

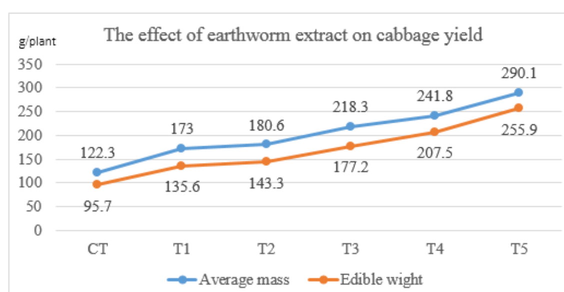

Fig. 4: Average plant biomass after harvest

Figure 5 demonstrates that the EE application substantially increased the average fresh biomass per experimental plot of Chinese cabbage. The most pronounced improvement was observed in T5, which obtained 4641.8 g/plot for total biomass and 4095 g/plot for edible biomass, while the control yielded only 1958.4 g/plot and 1533.6 g/plot, respectively. Treatments T3 and

T4 also showed remarkable gains, ranging from approximately 3500–3900 g/plot, confirming the significant effect of EE on yield enhancement.

These results are consistent with the findings of Olle et al. [31], who reported that vermicompost and its liquid extracts enhance crop yield by improving nutrient uptake, stimulating root and shoot development, and increasing chlorophyll concentration and photosynthetic rate. Bioactive compounds and beneficial microorganisms present in EE also promote hormone-like effects that support better assimilate partitioning to economically important plant parts, thereby increasing marketable yield [18].

The results demonstrated that EE had a strong positive effect on the growth performance of Chinese cabbage. All treated plants (T1–T5) exhibited enhanced morphological development compared to the control, including improvements in plant height, leaf number, canopy width, and stem base diameter. Among treatments, T5 consistently recorded the highest values, indicating better biomass accumulation and photosynthetic capacity.

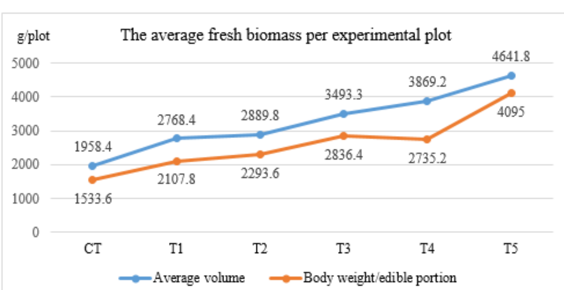

Fig. 5: Average fresh biomass per experimental plot of Chinese cabbage after harvest

Figure 6 shows that both the theoretical and actual yields of Chinese cabbage increased consistently with higher concentrations of EE. In the control (CT), the theoretical yield was 19,584 kg/ha, while the actual yield was 12,270 kg/ha. These values increased progressively across treatments, reaching 46,419 kg/ha and 32,757 kg/ha in T5, respectively. A clear upward trend was observed from T1 to T5. For example, actual yield increased from 17,367 kg/ha (T1) to 26,570 kg/ha (T4), and further to 32,757 kg/ha (T5). Similarly, the theoretical yield rose steadily from 27,683 kg/ha (T1) to 38,691 kg/ha (T4), indicating a strong response to increasing EE concentrations. Higher treatments (T3–T5) showed markedly greater yields compared to lower levels (T1–T2). The difference between CT and T5 was substantial, with actual yield increasing by more than 20,000 kg/ha. This indicates that EE significantly enhanced biomass accumulation and yield formation.

These findings are in line with the study by Phan Hoang An et al. [17], who reported that vermicompost extract (SW95+) significantly improved crop productivity, with yields increasing by 2.39, 2.58, and 1.62 times for Chinese cabbage, Malabar spinach, and water spinach, respectively, compared to the control. Similarly, Son Thi Thanh Nga et al. [28] demonstrated that yield increased with higher concentrations of vermicompost extract, with the highest yield reaching approximately 56.8 t/ha at the 60 mL treatment. In addition, Luu Thi Thuy Hai et al. [22] reported that the yield of Chinese cabbage increased proportionally with vermicompost application rates, with the highest yield (29.13 t/ha) achieved at 20 t/ha, representing a 226.20% increase compared to the control.

The enhanced productivity may be attributed to EE, which contains a wide range of beneficial microorganisms, including nitrogen-fixing and phosphorus-solubilizing bacteria [31], as well as plant growth-regulating compounds such as gibberellins, auxins, cytokinins, vitamins, humic acids, and defensive enzymes [32]. The combination of these components contributes significantly to promoting plant growth and development, thereby enhancing crop productivity [33]. Therefore, under the conditions of this study, T5 is recommended as the optimal application level, highlighting its potential in sustainable and efficient Chinese cabbage production.

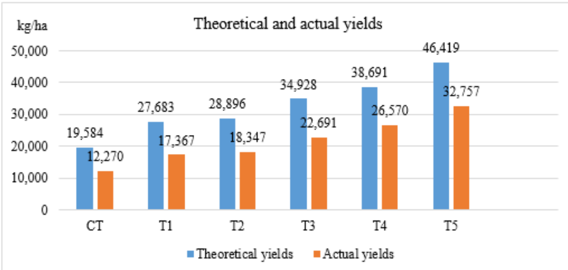

Fig. 6: Theoretical and actual yields of Chinese cabbage after harvest

Table 8: Bitterness and crispness of Chinese cabbage

Treatment	Assessment	
	Bitterness	Crispness
CT (0 ml)	2	1
T1 (20 ml)	2	1
T2 (25 ml)	2	1
T3 (30 ml)	3	2
T4 (35 ml)	3	2
T5 (40 ml)	3	2

F. Sensory evaluation

Product quality is an important factor determining marketability and plays a key role in promoting vegetable production. In this study, the sensory quality of Chinese cabbage was evaluated based on bitterness and crispness [34] (Table 8).

Although the panel size was limited, all evaluators were trained specialists in agriculture with experience in sensory assessment of vegetables, ensuring consistency and reliability of the results. Regarding bitterness, treatments from CT to T2 all recorded a score of 2 (slightly bitter), whereas treatments from T3 to T5 reached a score of 3, indicating a reduction in bitterness. This suggests that increasing EE concentrations may contribute to improving taste by reducing undesirable bitterness.

In terms of crispness, CT, T1, and T2 were rated at 1 (tough), while treatments from T3 to T5 achieved a score of 2 (crisp). This indicates that higher EE concentrations improved leaf texture, resulting in better crispness.

Overall, treatments T3, T4, and T5 showed superior sensory quality, with reduced bitterness and improved crispness, among which T5 was the most effective. These improvements may be associated with the enhanced nutrient availability provided by EE, particularly micronutrients that support plant metabolism and tissue development, thereby contributing to better texture and taste quality [18].

V. CONCLUSION

The results of this study demonstrated that foliar application of EE significantly improved the growth, development, yield, and sensory quality of Chinese cabbage under field conditions in Tra Vinh Ward, Vinh Long Province. All treatments supplemented with EE (T1–T5) showed better performance than the control, with noticeable improvements in plant height, leaf number, canopy width, stem base diameter, biomass accumulation, and yield. Among the treatments, T5 (40 mL/20 L) consistently produced the highest values across all growth and yield parameters, indicating its superior effectiveness in enhancing plant productivity. In addition, this treatment also improved sensory attributes by reducing bitterness and increasing crispness, thereby contributing to better product quality. Therefore, the 40 mL concentration is recommended to maximize yield and quality under similar conditions, while promoting a sustainable alternative to chemical fertilizers.

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