

Research Article

Effect of vermicompost and organic fertilizer on the growth, yield, and quality of lettuce (*Lactuca sativa* L.)

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Abstract - This experiment aimed to investigate the effects of vermicompost and different rates of organic fertilizer on the growth, yield, and quality of organic lettuce (*Lactuca sativa* L.). A Completely Randomized Design was employed with nine treatments, four replications, and ten plants per replication. The study was conducted from January to June 2023 at the nursery of the Landscape Management Division, Building and Facilities Office, Mahasarakham University. The results indicated that the application of vermicompost and organic fertilizer significantly increased soil nutrient availability, including nitrogen, phosphorus, potassium, organic matter, and cation exchange capacity (CEC). Lettuce grown with the application of organic fertilizer at the rate of 38.7 g plant⁻¹ showed the largest improvement in growth and yield characteristics, including stem diameter, number of leaves, fresh weight, and dry weight. Furthermore, this treatment resulted in the highest levels of lettuce quality attributes, particularly total soluble solids and chlorophyll content.

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1. Introduction

Currently, Organic vegetable production has gained increasing popularity among health-conscious consumers. Lettuce is a widely consumed vegetable, and cultivating it with organic fertilizers is a production approach that emphasizes the sustainability of agricultural systems alongside the conservation of soil resources and the environment. The use of organic fertilizers, such as manure, compost, or biofertilizers, helps increase soil organic matter, improve soil structure, and enhance water and air circulation, thereby allowing lettuce roots to develop efficiently. In addition, the nutrients that are gradually released from organic fertilizers continuously nourish the plants, promoting uniform growth, reducing the risk of chemical residue accumulation, and enhancing the nutritional quality of the produce. In 2025, reports indicated that cultivation covered more than 3,000 rai, with a total annual yield of over 4,325 tons. The average productivity was as high as 1,493 kilograms per rai, with an average selling price of 28.82 baht per kilogram, generating stable income for farmers and their families ([Department of Agricultural Extension, 2025](#)). Organic farming practices can be implemented through various approaches, with the application of organic fertilizers, such as vermicompost and compost derived from leaf and grass residues, being one of the most widely adopted methods among farmers. These fertilizers are considered environmentally friendly and safe for humans and animals. Vermicompost, in particular, is produced from the decomposition of organic matter through the digestive processes of earthworms and associated microorganisms. It is characterized by its granular, dark-colored structure, high porosity, and excellent water-holding capacity ([Tanco, 2005](#)). As such, vermicompost is suitable for improving soil conditions and enhancing plant

growth. Moreover, vermicompost contains readily available nutrients, including nitrogen, phosphorus, potassium, calcium, and magnesium ([Thammarat et al., 2020](#)). [Jintarit and Na Lampang \(2018\)](#) reported that the application of biochar increased soil organic carbon, which helps buffer or retain excess hydrogen ions released in acidic soils, thereby improving soil reactions. Moreover, when biochar is used in combination with organic materials such as manure or compost, it contributes to increasing nutrient availability in the soil while also supporting the management of agricultural residues and the utilization of locally available materials. Moreover, cultivating lettuce with organic fertilizers helps reduce production costs in the long term, as it enhances and sustains soil fertility while decreasing dependence on chemical fertilizers and pesticides. It also increases consumer confidence by ensuring that the produce is safe and of high quality, in alignment with organic farming practices and environmentally friendly food production.

Recognizing the importance of waste management in promoting sustainable development, Mahasarakham University has initiated waste reduction programs in alignment with the Green University framework, particularly under Indicator 3 Waste and Wastewater Management. The Landscape Management Division of the university has developed projects to convert organic waste, such as grass clippings, pruned branches, and leaf residues, into vermicompost and compost. These organic fertilizers are subsequently utilized in landscaping and crop cultivation within the university premises. Vermicompost consists of various organic residues, including soil and microorganisms, that have been decomposed through the digestive process of earthworms and excreted as casts. The resulting vermicompost is characterized by fine, granular particles with a dark brown to

black color; it is lightweight and porous, with excellent water and air permeability, high moisture-holding capacity, and a high organic matter content. It also contains plant nutrients in forms that are readily available for plant uptake in relatively high amounts (Sri-saard & Jai-saen, 2010).

Previous studies have reported the beneficial effects of vermicompost combined with growing media on pak choy (Wang et al., 2010) and on ornamental plants. For instance, Dechsoungnoen (2016) demonstrated that composted woody residues significantly improved the growth and appearance of potted ornamental plants, resulting in greener and glossier leaves. The study also emphasized that optimal composting requires 60–90 days of decomposition before application. Overall, the use of vermicompost and organic fertilizers has been shown to enhance plant growth, increase resistance to diseases, improve yields, and promote sustainable food production. Therefore, this study aimed to investigate the effects of vermicompost and different rates of organic fertilizer on the growth, yield, and quality of organic lettuce (*Lactuca sativa* L.), with the ultimate goal of providing insights for potential commercial applications.

2. Materials and methods

2.1 Plant preparation and transplanting

The experiment began with sowing 'Grand Rapids' lettuce seeds in seedling trays. When the seedlings reached 21 days of age, they were transplanted into 5x8-inch black polyethylene bags, totaling 360 bags for the entire study. Each bag contained a single seedling. The plants were maintained following standard practices, and growth data were recorded at 35 days after transplanting.

2.2 Fertilizer production and application

The vermicompost and organic fertilizer used in this study were produced by the Waste Management Unit of the Buildings and Grounds Division at Mahasarakham University. The vermicompost was derived from African Night Crawler earthworms fed with food waste, specifically vegetable and fruit scraps collected from shops within the university. The organic fertilizer was produced by mixing grass clippings and fallen leaves with manure and biochar or burnt rice husk. This mixture was decomposed using an effective microorganism solution diluted at a ratio of 1 to 10 liters. During the composting process, water was applied for 10 minutes daily, and the pile was turned weekly to ensure proper aeration. The organic fertilizer required approximately 45 to 60 days to fully decompose, or until it turned a dark color, indicating it was ready for use. Regarding the application method, the fertilizer for each treatment was divided into three equal parts. The first part was incorporated into the planting medium, which consisted of loamy soil and charcoal at a 1 to 1 ratio, prior to transplanting. The remaining two parts were applied as top-dressing at 10 and 20 days after transplanting, respectively.

2.3 Experimental design and treatments

The experiment was arranged in a Completely Randomized Design (CRD) consisting of nine treatments, with four replicates per treatment and ten plants per replicate. The treatments were defined as follows. Treatment 1 served as the control group, where no vermicompost or organic fertilizer was applied. Treatments 2, 3, 4, and 5 involved the application of vermicompost at rates of 12.9, 25.8, 38.7, and 51.6 g plant⁻¹, respectively. For the organic fertilizer treatments, Treatments 6, 7, 8, and 9 consisted of application rates of 12.9, 28.5, 38.7, and 51.6 g plant⁻¹, respectively.

2.4 Data collection

2.4.1 Soil analysis before and after the experiment

A composite soil sample was randomly collected prior to the study to establish baseline data for pH, organic matter, cation exchange capacity, and nutrient content, including nitrogen, phosphorus, and potassium. Following the conclusion of the experiment, 36 soil samples were randomly collected across all treatments to analyze post-experimental soil pH, cation exchange capacity, and organic matter. Specific analytical procedures included the Kjeldahl method for nitrogen, the Bray II method for phosphorus, and the cobalt nitrite method for potassium.

2.4.2 Lettuce growth and yield components

Plant growth parameters were recorded 35 days after transplanting. Stem diameter was measured in centimeters using a Vernier caliper, while the number of leaves was recorded as leaves per plant. For biomass determination, plants were weighed to obtain the fresh weight in grams per plant, then oven-dried at 60°C for 72 hours to determine the final dry weight.

2.4.3 Quality analysis

Total soluble solids were determined using an N-1E model hand refractometer. Titratable acidity and vitamin C content were measured according to the methods of the [Association of Official Analytical Chemists \(1984 & 1990\)](#), respectively. Additionally, chlorophyll levels were measured in SPAD units using a SPAD meter, with measurements taken from the middle of the leaves between 9:00 AM and 12:00 PM.

3. Results

The experimental results regarding the effects of various application rates of vermicompost and organic fertilizer on the growth, yield, and quality of lettuce are presented below.

3.1 Soil properties and nutrient content

The application of vermicompost and organic fertilizer at different rates significantly influenced several soil properties. Total nitrogen content in the soil was significantly affected by the various treatments, with all experimental groups showing statistically significant differences compared to the control. Similarly, available phosphorus levels were significantly impacted by the application rates. The highest increases in available phosphorus were observed in Treatment 5 (vermicompost at 51.6 g plant⁻¹), Treatment 8 (organic fertilizer at 38.7 g plant⁻¹), and Treatment 9 (organic fertilizer at 51.6 g plant⁻¹), which yielded values of 13.373, 13.383, and 13.355 mg kg⁻¹, respectively. In contrast, Treatment 1 (control) exhibited the lowest available phosphorus content. However, the experiment indicated that the different rates of organic amendments had no significant effect on extractable potassium content, with no statistical differences observed among the treatments.

Furthermore, the application of these fertilizers led to a significant increase in soil organic matter across all treatments. The most substantial improvements were recorded in Treatments 3, 4, 5, 7, 8, and 9, which resulted in organic matter percentages of 1.385, 1.297, 1.357, 1.322, 1.407, and 1.382, respectively. The soil cation exchange capacity (CEC) was also highly significantly affected by the treatments, showing marked statistical differences across the study groups. Additionally, the various rates of vermicompost and organic fertilizer exerted a highly significant influence on soil pH, with all treatments demonstrating highly significant statistical variations, as detailed in Table 1.

Table 1. Effects of vermicompost and organic fertilizer on total nitrogen, available phosphorus, extractable potassium, organic matter, cation exchange capacity, and soil pH.

Treatment	Total N (%)	Available P (mg/kg)	Extractable K (mg/kg)	Organic Matter: OM (%)	Cation Exchange Capacity (meq / Soil 100 g)	pH
Before Planting	0.052	5.385	67.340	0.692	8.212	5.520
T1	0.052C	8.503E	68.933	0.702B	9.880B	5.650C
T2	0.062ABC	11.163D	70.155	0.770B	10.670B	5.700C
T3	0.072ABC	12.583AB	72.633	1.385A	12.250A	6.370AB
T4	0.065ABC	12.323ABC	74.640	1.297A	12.033A	6.350AB
T5	0.067ABC	13.373A	74.645	1.357A	12.155A	6.420A
T6	0.055BC	11.320CD	73.390	0.807B	10.755B	6.200AB
T7	0.060ABC	12.073BCD	74.390	1.322A	12.017A	6.050B
T8	0.070AB	13.383A	74.652	1.407A	12.283A	6.120AB
T9	0.065ABC	13.355A	74.680	1.382A	12.160A	6.170AB
F-test	*	**	ns	**	**	**
LSD ($p \leq 0.05$)	0.0168	1.1292	8.4040	0.1806	1.0704	0.3359
CV. (%)	18.23	6.48	7.92	10.74	6.37	3.78

Note: Column values with different letters indicate significant differences ($p \leq 0.05$; Least Significant Difference (LSD) test). Statistical significance is denoted by * ($p \leq 0.05$) and ** ($p \leq 0.01$), while “ns” indicates no statistical significance. Treatment abbreviations are defined as follows: T1 represents the control. T2, T3, T4, and T5 represent vermicompost applications at rates of 12.9, 25.8, 38.7, and 51.6 g plant⁻¹, respectively. T6, T7, T8, and T9 represent organic fertilizer applications at rates of 12.9, 25.8, 38.7, and 51.6 g plant⁻¹, respectively. CV = Coefficient of Variation.

3.2 Plant growth

From the results of the experiment on the application of vermicompost and organic fertilizer at different rates on the growth of lettuce, it was found that the application rates had a significant effect on the stem diameter of lettuce plants. The differences among treatments were statistically significant. Treatments 8 and 9 produced the highest average stem diameters at harvest, measuring 3.73 cm and 3.61 cm, respectively. In contrast, Treatment 1 (control) produced the smallest average stem diameter of 2.55 cm (Table 2). Regarding the number of leaves, the application of vermicompost and

organic fertilizer at different rates also showed a statistically significant effect. Treatment 8 resulted in the highest average number of leaves per plant (21.54 leaves), while Treatment 1 (control) produced the lowest average number of leaves (17.98 leaves) (Table 2).

For the dry weight of lettuce plants, the results showed that different rates of vermicompost and organic fertilizer significantly affected plant dry weight. The application of organic fertilizer at a rate of 38.7 g plant⁻¹ (Treatment 8) resulted in the highest average dry weight at harvest, 9.347 g per plant, while the control treatment (Treatment 1) produced

the lowest dry weight, 6.727 g per plant (Table 2).

3.3 Yield components

For the yield components of lettuce, it was found that the application of vermicompost and organic fertilizer at different rates had a statistically significant effect on the fresh weight of lettuce plants. The treatments showed highly significant differences. The application of vermicompost at the rate of 25.8 g plant⁻¹ (Treatment 3),

vermicompost at 51.6 g plant⁻¹ (Treatment 5), organic fertilizer at 25.8 g plant⁻¹ (Treatment 7), organic fertilizer at 38.7 g plant⁻¹ (Treatment 8), and organic fertilizer at 51.6 g plant⁻¹ (Treatment 9) resulted in the highest average fresh weights per plant, measuring 57.23, 57.13, 57.24, 59.05, and 58.25 g/plant, respectively. In contrast, the control treatment (Treatment 1) produced the lowest average fresh weight of 43.73 g/plant (Table 2).

Table 2. Effects of vermicompost and organic fertilizer on growth and yield components of lettuce at harvest.

Treatment	Stem Diameter (cm)	Number of Leaves (leaves/plant)	Dry Weight (g/plant)	Fresh Weight (g/plant)
T1	2.550E	17.980D	6.727G	43.730D
T2	2.800CDE	19.600C	7.270F	52.430C
T3	3.380AB	21.060AB	8.130CD	57.230A
T4	3.040BCDE	20.610ABC	7.610EF	56.980AB
T5	3.300ABCD	20.360ABC	7.825DE	57.130A
T6	2.780DE	19.860BC	7.490EF	52.930BC
T7	3.330ABC	20.380ABC	8.247C	57.240A
T8	3.730A	21.540A	9.347A	59.050A
T9	3.610A	21.150AB	8.727B	58.250A
F-test	**	**	**	**
LSD ($p \leq 0.05$)	0.5456	1.3272	0.3693	4.1080
CV. (%)	11.84	4.51	3.21	5.15

Note: Column values with different letters indicate significant differences ($p < 0.05$; Least Significant Difference (LSD) test). Statistical significance at the 0.01 probability level is denoted by **. The experimental treatments are defined as follows: T1 represents the control group with no organic amendments. T2, T3, T4, and T5 represent the application of vermicompost at rates of 12.9, 25.8, 38.7, and 51.6 g plant⁻¹, respectively. For the organic fertilizer treatments, T6, T7, T8, and T9 represent application rates of 12.9, 25.8, 38.7, and 51.6 g plant⁻¹, respectively. CV = Coefficient of Variation.

3.4 Quality components

The application of various rates of vermicompost and organic fertilizer exerted a highly significant influence on the total soluble solids (TSS) content of lettuce. Treatment 8, which received organic fertilizer at a rate of 38.7 g plant⁻¹, achieved the highest TSS value (0.887 °Brix). In contrast, the analysis of titratable acidity and vitamin C content revealed no

statistically significant differences among the experimental treatments.

Regarding chlorophyll content, the different application rates of vermicompost and organic fertilizer showed a highly significant effect on SPAD values in lettuce. Treatment 8 resulted in the highest chlorophyll content (12.425 SPAD units), which was not significantly different from Treatments 4, 5, and 7. The

lowest chlorophyll content was recorded in the control group (T1), with a value of 8.215 SPAD units. Detailed results for

these quality attributes are presented in Table 3.

Table 3 Effects of vermicompost and organic fertilizer on quality components of lettuce at harvest.

Treatment	Total Soluble Solids (°Brix)	Titrateable Acidity (%)	Vitamin C (mg/fresh weight)	Chlorophyll Level (SPAD Unit)
T1	0.580C	0.175	14.023	8.215C
T2	0.615C	0.173	14.168	11.227B
T3	0.620C	0.171	14.163	11.410B
T4	0.727BC	0.175	14.342	12.268A
T5	0.697BC	0.173	14.315	12.263A
T6	0.622C	0.174	14.333	11.305B
T7	0.640BC	0.175	14.210	11.393B
T8	0.887A	0.176	14.385	12.425A
T9	0.780AB	0.174	14.248	12.313A
F-test	**	ns	ns	**
LSD ($p \leq 0.05$)	0.1573	4.9000	0.3512	0.4545
CV. (%)	15.82	1.94	1.70	2.74

Note: Column values with different letters indicate significant differences ($p \leq 0.05$; Least Significant Difference (LSD) test). Statistical significance at the 0.01 probability level is denoted by **, while “ns” indicates no statistically significant difference. The experimental treatments are defined as follows: T1 represents the control group. T2, T3, T4, and T5 represent the application of vermicompost at rates of 12.9, 25.8, 38.7, and 51.6 g plant⁻¹, respectively. T6, T7, T8, and T9 represent the application of organic fertilizer at rates of 12.9, 25.8, 38.7, and 51.6 g plant⁻¹, respectively. CV = Coefficient of Variation.

4. Discussion

Based on the study of the effects of vermicompost and organic fertilizer on the growth, yield, and quality of lettuce, the pre-planting soil analysis (Table 1) revealed that total nitrogen content was very low (0.052%), available phosphorus was low (5.385 mg/kg), and potassium was at a medium level (67.340 mg/kg). Soil organic matter was low at 0.692%, Cation Exchange Capacity (CEC) was 8.212 meq/100g soil, and soil pH was 5.520. After collecting soil samples from all treatments, it was found that Treatment 8 (organic fertilizer at 38.7 g plant⁻¹) significantly increased soil nutrients, including nitrogen, phosphorus, and organic matter, as well as the soil’s CEC. The values were 0.070%, 13.383 mg/kg,

1.407%, and 12.283 meq/100g soil, respectively. [Brady and Weil \(2010\)](#) stated that adding organic matter to the soil through organic fertilizers, such as leaf litter, which contains cellulose, hemicellulose, and lignin, will increase soil organic matter as it decomposes into humus. This organic matter is crucial for improving soil structure, increasing water retention, improving aeration, and enhancing the soil’s CEC. This, in turn, allows nutrients to remain in the soil longer and be released throughout the growing season, converting organic minerals into inorganic minerals that result in higher yields ([Miller et al., 2002](#)). It also slows the decline of soil organic matter and the degradation of agricultural soil, while improving its physical and biological

properties (Tancho, 2005). These factors affect plant growth and yield. Therefore, to achieve long-term, worthwhile returns from farming, organic matter should be added to the soil to create a balance between its various functions, which ultimately relates to crop yields. Moreover, Nimpanich et al. (2025) reported that the application of 100% vermicompost resulted in the highest fresh and dry weights of Chinese kale (cv. Hed Hom). The experimental results indicate that vermicompost can be effectively used as a growing medium for crop production. According to the report by Nilawonk (2020), the amounts of organic matter, total nitrogen, available phosphorus, exchangeable potassium, and the yields of okra, Chinese cabbage, and kale increased when appropriate levels of organic fertilizers and bio-extracts were applied. Similarly, Lesing and Aungoolprasert (2016) found that the concentration of pigments, which play an essential role in the photosynthetic process of kale, increased when the plants received organic fertilizers with high nitrogen content.

In terms of lettuce growth and yield, Treatment 8 (organic fertilizer at 38.7 g plant⁻¹) resulted in the highest stem diameter, number of leaves, and dry and fresh weight. Organic fertilizer not only provides essential macro- and micronutrients for plant growth but also improves soil structure, leading to better drainage and aeration. It helps increase the stability of soil aggregates and serves as a nutrient source for beneficial soil microorganisms, making their activities more efficient and increasing their population. This promotes better lettuce growth and increased yield. Additionally, high rates of organic fertilizer help increase nitrogen levels in the soil, which is a key element for the synthesis of chlorophyll, amino acids, and proteins. This promotes photosynthesis and cell division, resulting in larger stem diameters

and an increased number of leaves (Brady & Weil, 2010). Palm et al. (2001) also reported that when soil is friable and retains water well, lettuce roots can absorb water and nutrients fully, leading to a high amount of water in the plant tissue and thus an increase in fresh weight. Meanwhile, Siringam and Boonmee (2021) reported that Red Oak lettuce plants that were not sprayed with bio-extracts (control treatment) exhibited the greatest growth performance in terms of plant height, number of leaves, canopy width, fresh shoot weight, dry shoot weight, and dry shoot biomass. This is because the plants received appropriate amounts of macro- and micronutrients required for metabolic processes related to plant growth and development (Chenard et al., 2005). These findings are consistent with the experiment conducted by Siringam et al. (2019), who reported that Green Oak lettuce grown in the "Pranakorn" nutrient solution showed the highest number of leaves, canopy width, fresh root weight, dry root weight, dry root biomass, fresh shoot weight, dry shoot weight, and dry shoot biomass when compared with Green Oak lettuce grown in the Pranakorn nutrient solution supplemented with earthworm cast extract at different ratios. The study by Phueankhamhai and Kaewtaphan (2021), which investigated the use of appropriate rates of vermicompost to compare the growth rates of red coral lettuce and red oak lettuce, found that the application of vermicompost at a rate of 2,000 kg per rai resulted in the greatest plant height for both lettuce types. The maximum heights recorded were 12.82 cm for red coral lettuce and 12.55 cm for red oak lettuce, respectively.

In terms of the quality of the lettuce yield, Treatment 8 (organic fertilizer at 38.7 g plant⁻¹) resulted in the highest total soluble solids and chlorophyll levels. This is because the application of organic fertilizer at this rate caused a change in

soil nutrients, leading to increased levels of nitrogen, phosphorus, potassium, and soil organic matter. The lettuce plants were able to absorb more water and mineral nutrients from the soil, which also improved the quality of the yield. This is consistent with the report by [Sa-nguenngoen et al. \(2013\)](#), which stated that a benefit of using organic fertilizer is that it improves soil quality. When the soil is friable, it increases its water-holding capacity by creating air pores, allowing the soil to slowly release nutrients to the plants. This keeps nutrients in the soil longer and improves the function of soil microorganisms. And the application of vermicompost resulted in the highest potassium content in lettuce leaves ([Abd-Elrahman et al., 2022](#)). However, a limitation of organic fertilizers is that they contain lower levels of plant nutrients compared with chemical fertilizers at the same application rate. To supply nutrients equivalent to those provided by chemical fertilizers, a larger amount of organic fertilizer is required ([Land Development Department, 2021](#)). Therefore, the use of organic fertilizers with high nutrient contents in crop cultivation can help overcome the problem of the relatively low nutrient levels of organic fertilizers, enabling them to provide nutrients comparable to those supplied by chemical fertilizers.

Additionally, it is important to acknowledge a limitation of this study regarding the experimental design. Due to specific constraints, a chemical fertilizer control treatment was not included in this trial. Therefore, a direct comparison between the organic amendments and conventional chemical fertilizers could not be established. Future research should incorporate standard chemical controls to provide a more comprehensive benchmark for yield and quality performance. From an economic perspective, utilizing locally available organic waste such as food scraps, grass clippings, and leaf residues

to produce vermicompost and organic fertilizer offers a significant cost advantage over purchasing commercial chemical fertilizers. While the production process involves labor for preparation and maintenance, the elimination of direct expenses for commercial fertilizer procurement substantially reduces overall production costs. This approach aligns with the sufficiency economy philosophy by lowering input dependency, thereby potentially increasing the net income stability for farmers compared to conventional chemical-based systems.

The results of this experiment will serve as valuable information for promoting knowledge and providing an alternative for using organic fertilizers that are both high-quality and safe for the environment. Recognizing the importance of waste management in promoting sustainable development, Mahasarakham University has initiated waste reduction programs in alignment with the Green University framework, particularly under Indicator 3 Waste and Wastewater Management. The Landscape Management Division of the university has developed projects to convert organic waste, such as grass clippings, pruned branches, and leaf residues, into vermicompost and compost. These organic fertilizers are subsequently utilized in landscaping and crop cultivation within the university premises. The knowledge gained from this study can also be applied to farmers' crop production to enhance their quality of life based on the philosophy of a sufficient economy and to add value to agricultural products more efficiently.

5. Conclusions

The application of vermicompost and organic fertilizer increased soil nutrient content, including nitrogen, phosphorus, potassium, and organic matter, and also improved the soil's cation exchange capacity. Growing lettuce with organic fertilizer at a rate of 38.7 g plant⁻¹ resulted

in the highest growth and yield, including the largest stem diameter, largest number of leaves, and largest dry and fresh weight. It also led to the highest total soluble solids and chlorophyll levels. Based on these findings, it is recommended that future research investigate the long-term effects of appropriate application rates of organic fertilizers on soil structure and their potential application to other economic crops to promote sustainable agricultural practices. These results demonstrate that utilizing university-produced organic amendments not only enhances crop productivity but also provides a viable waste management strategy for sustainable campus development.

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