Growth and Yield Optimization of Kale (*Brassica oleracea* var. Acephala) through Vegetable Waste Liquid Fertilizer and Leaf Compost

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Abstract
The growing demand for functional foods with high nutritional value, along with increasing public awareness of a healthy lifestyle, has led to a continuous rise in kale consumption in Indonesia. The use of organic fertilizers offers an environmentally friendly and sustainable solution. This study examines the effectiveness of combining liquid organic fertilizer derived from vegetable waste with leaf compost on the growth and yield of kale plants. The experimental method employed a factorial Randomized Block Design consisting of two factors. The first factor was the application of liquid organic fertilizer at three levels: S_0 = 0 ml/L of water, S_1 = 50 ml/L of water, and S_2 = 100 ml/L of water. The second factor was leaf compost with four levels: K_0 = 0 g/polybag, K_1 = 100 g/polybag, K_2 = 200 g/polybag, and K_3 = 300 g/polybag. The results showed that the application of liquid organic fertilizer from vegetable waste and leaf compost had a highly significant effect on plant height, number of leaves, stem diameter, and fresh weight of plants. However, the interaction between the two treatments exhibited no significant effect on all observed parameters.

Keywords:

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2nd International Conference on Islamic Community Studies (ICICS)
Theme: History of Malay Civilisation and Islamic Human Capacity and Halal Hub in the Globalization Era

Introduction

Kale (*Brassica oleracea* var. acephala) is one o;f the green leafy vegetables from the Brassicaceae family that has high nutritional value, particularly vitamins A, C, and K, as well as calcium, iron, and antioxidants [7]. The demand for kale in Indonesia has been increasing along with the trend of a healthy lifestyle and the need for functional foods rich in nutrients. However, the productivity of kale at the farmer level still faces challenges, one of which is the continuous use of chemical fertilizers that can reduce soil fertility and cause environmental pollution [12].

As an alternative, the use of organic fertilizers offers an environmentally friendly and sustainable solution. Liquid organic fertilizer derived from vegetable waste contains essential macro and micronutrients and can enhance soil microbial activity, thereby improving plant growth. Vegetable waste that is usually discarded can be processed into liquid fertilizer through fermentation, which not only reduces organic waste but also adds value to the agricultural sector [4].

In addition to liquid organic fertilizer, the use of leaf compost also plays an important role in improving soil structure, increasing water-holding capacity, and providing nutrients for plants. Leaf compost is rich in organic matter that can enhance soil fertility naturally and sustainably. The combination of liquid organic fertilizer from vegetable waste and leaf compost is expected to have a positive effect on the growth and yield of kale plants, both in terms of quality and quantity of production [3].

The application of liquid organic fertilizer from vegetable waste combined with leaf compost has the potential to improve the growth and yield of kale. In addition to increasing productivity, the use of organic fertilizers also supports the principles of sustainable and environmentally friendly agriculture while providing a solution to the increasing amount of organic waste generated from households and traditional markets. Therefore, this study is important to examine the effectiveness of combining liquid organic fertilizer from vegetable waste and leaf compost on the growth and yield of kale.

Literature Review

Kale (*Brassica oleracea* var. *acephala*) has thick, curly, dark green leaves with a relatively strong fibrous root system. Optimal kale growth is strongly influenced by the growing media conditions, nutrient availability, and environmental factors such as light, temperature, and humidity. Nitrogen is the main factor determining the vegetative growth of kale, especially in leaf formation [7].

Liquid organic fertilizer is the result of fermenting organic materials such as vegetable waste, animal manure, or agricultural residues that contain macronutrients (N, P, K) and micronutrients (Fe, Zn, Cu, Mn) in liquid form [4]. Liquid organic fertilizer functions to increase nutrient availability in the soil, improve soil microbial activity, and accelerate plant growth. The nitrogen content in liquid organic fertilizer plays an essential role in the formation of chlorophyll required for photosynthesis. With increased photosynthetic activity, vegetative growth such as leaf and stem development becomes more optimal [14].

Leaf compost is the product of decomposed organic matter such as dry leaves, grasses, and plant residues that are rich in nutrients and organic compounds. The use of compost can improve the physical, chemical, and biological properties of the soil. According to [3], leaf compost can increase the soil's water-holding capacity, improve aeration, and enhance the activity of microorganisms involved in nutrient cycling. In addition, compost enriches the organic matter content of the soil, thereby improving soil fertility naturally and sustainably.

The use of compost in organic farming systems is an important step toward sustainable agriculture because it helps maintain soil ecosystem balance without relying on synthetic chemical fertilizers [12].

Research Methodology

This research was conducted on Jalan Karya No. 22, Medan, from July to September 2025. The tools used in this study included a hoe, machete, measuring tape, watering can, sprayer, rope, barrel (bucket), polybags, scale, hose, wood, nails, marker, ruler, pen, notebook, and mobile phone (camera). The materials used consisted of vegetable waste, EM4, molasses, water, bran, leaves, and kale seeds. The experimental method applied was a Factorial Randomized Block Design consisting of two factors. The first factor was the application of liquid organic fertilizer, divided into three levels: S_0 = 0 ml/L water, S_1 = 50 ml/L water, and S_2 = 100 ml/L water. The second factor was the application of leaf compost, divided into four levels: K_0 = 0 g/polybag, K_1 = 100 g/polybag, K_2 = 200 g/polybag, and K_3 = 300 g/polybag. The observed parameters included plant height, number of leaves, stem diameter, and plant fresh weight. Data were analyzed using Analysis of Variance (ANOVA) to examine the effect of treatments and their interactions, while data processing and analysis were performed using Microsoft Excel.

Results and Discussion

4.1 Plant Height (cm)

The results of the analysis of variance (ANOVA) showed that the application of liquid organic fertilizer from vegetable waste and leaf compost had a highly significant effect on plant height (cm). However, the interaction between the two treatments did not show a significant effect on plant height. These findings indicate that each treatment independently contributed to the growth of kale, but their combination did not produce a synergistic interaction. The detailed results of the observation are presented in Table 1.

Table 1. Average Plant Height of Kale as Affected by the Application of Liquid Organic Fertilizer from Vegetable Waste and Leaf Compost.

Treatment	Plant Height (cm)
S = Liquid Organic Fertilizer (Vegetable Waste)	
S_0 = 0 ml/L water	18,01 bB
S_1 = 50 ml/ L water	18,65 bA
S_2 = 100 ml/ L water	19,08 aA
K = Leaf Compost	
K_0 = 0 g/polybag	16,98 cC
K_1 =100 g/polybag	18,52 bB
K_2 = 200 g/polybag	18,83 bB
K_3 = 300 g/polybag	19,99 aA

Note: Numbers followed by the same letters in the same column indicate no significant difference at the 5% level (lowercase letters) and at the 1% level (uppercase letters) according to Duncan's Multiple Range Test (DMRT).

The application of liquid organic fertilizer (LOF) from vegetable waste had a significant effect on increasing the height of kale plants. This is because vegetable waste LOF contains macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as micronutrients that are easily absorbed by plants. Nitrogen plays an essential role in chlorophyll formation and photosynthesis, thereby supporting vegetative growth, including the increase in plant height [6]. In addition, the organic compounds in LOF can enhance soil microbial activity, which improves nutrient availability and promotes root development for more optimal nutrient absorption [11].

Similarly, leaf compost contains essential macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), which are important for vegetative growth, particularly in the processes of cell division and stem elongation, thus contributing to an increase in plant

height [10]. Moreover, compost can enhance soil microbial activity, improve aeration, and increase water-holding capacity, thereby creating a more favorable root environment that supports nutrient uptake for plant growth [8].

4.2 Number of Leaves

Based on the results of the analysis of variance (ANOVA), the application of liquid organic fertilizer from vegetable waste and leaf compost had a highly significant effect on the number of leaves. However, the interaction between the two treatments did not show a significant effect on leaf number. The results of these observations are presented in Table 2.

Table 2. Average Number of Leaves of Kale as Affected by the Application of Liquid Organic Fertilizer from Vegetable Waste and Leaf Compost.

Treatment	Number of Leaves (leaves)
S = Liquid Organic Fertilizer (Vegetable Waste)	
S_0 = 0 ml/ L water	9,33 bB
S_1 = 50 ml/ L water	10,42 aA
S_2 = 100 ml/ L water	10,75 aA
K = Leaf Compost	
K_0 = 0 g/polybag	9,17bB
K_1 =100 g/polybag	9,86 bB
K_2 = 200 g/polybag	9,94 bB
K_3 = 300 g/polybag	11,69 aA

Note: Numbers followed by the same letters in the same column indicate no significant difference at the 5% level (lowercase letters) and at the 1% level (uppercase letters) according to Duncan's Multiple Range Test (DMRT).

Liquid organic fertilizer from vegetable waste significantly affected the increase in the number of leaves due to its macro- and micronutrient content, which stimulates vegetative plant growth. The nitrogen contained in liquid organic fertilizer plays an important role in chlorophyll formation, thereby optimizing photosynthesis and producing sufficient energy for the development of new leaves [14]. In addition, the presence of potassium also supports the distribution of photosynthetic products to plant tissues, accelerating leaf development [9].

The increase in the number of leaves due to compost application is attributed to its ability to provide macronutrients, particularly nitrogen, which is essential during the vegetative growth phase. Nitrogen contributes to chlorophyll synthesis, enabling more efficient photosynthesis and supporting the formation of new leaves [8]. Recent studies have reported that the application of leaf-based compost significantly increases the number of leaves compared to treatments without compost, due to more stable and sustainable nutrient availability. Thus, the use of leaf compost is proven to be effective in supporting vegetative growth, particularly in increasing the number of leaves [2].

4.3 Stem Diameter (cm)

Based on the results of the analysis of variance (ANOVA), the application of liquid organic fertilizer from vegetable waste and leaf compost had a highly significant effect on stem diameter (cm). However, the interaction between the two treatments did not show a significant effect on stem diameter. The results of these observations are presented in Table 3.

Table 3. Average Stem Diameter of Kale as Affected by the Application of Liquid Organic Fertilizer from Vegetable Waste and Leaf Compost.

Perlakuan	Stem Diameter (cm)
S = Liquid Organic Fertilizer (Vegetable Waste)	
S_0 = 0 ml/ L water	0,89 bB
S_1 = 50 ml/ L water	0,96 bB
S_2 = 100 ml/ L water	1,01 aA
K = Leaf Compost	
K_0 = 0 g/polybag	0,87 bB
K_1 =100 g/polybag	0,95 aA
K_2 = 200 g/polybag	0,97 aA
K_3 = 300 g/polybag	1,03 aA

Note: Numbers followed by the same letters in the same column indicate no significant difference at the 5% level (lowercase letters) and at the 1% level (uppercase letters) according to Duncan's Multiple Range Test (DMRT).

The use of liquid organic fertilizer from vegetable waste significantly increased stem diameter because it provides complete nutrients that support cell division and enlargement. Nitrogen and phosphorus help form new tissues, while potassium strengthens cell walls, making the stems stronger and thicker [13].

The application of leaf compost also significantly affected the increase in kale stem diameter, as compost contains macro- and micronutrients that are released gradually, thereby providing a continuous supply of nutrients for plant growth. Nitrogen in compost stimulates cell division, while potassium contributes to strengthening cell walls and enhancing stem tissue turgor, leading to more optimal stem diameter growth [8].

4.4 Fresh Plant Weight (g)

Based on the analysis of variance, the application of liquid organic fertilizer from vegetable waste and leaf compost had a highly significant effect on fresh plant weight (g). However, their interaction did not have a significant effect on fresh plant weight. The observation results are presented in Table 4.

Table 4. Average Fresh Weight of Kale Plants as Affected by the Application of Liquid Organic Fertilizer from Vegetable Waste and Leaf Compost,

Treatment	Plant Fresh Weight (g)
S = Liquid Organic Fertilizer (Vegetable Waste)	
S_0 = 0 ml/ L water	78,20 bB
S_1 = 50 ml/ L water	79,98 aA
S_2 = 100 ml/ L water	80,95 aA
K = Kompos Dedaunan	
K_0 = 0 g/polybag	77,72 bB
K_1 =100 g/polybag	79,09 bB
K_2 = 200 g/polybag	79,63 bA
K_3 = 300 g/polybag	82,39 aA

Note: Numbers followed by the same letters in the same column indicate no significant difference at the 5% level (lowercase letters) and at the 1% level (uppercase letters) according to Duncan's Multiple Range Test (DMRT).

The increase in fresh plant weight is mainly due to the presence of macronutrients such as nitrogen, phosphorus, and potassium, which support photosynthesis, vegetative growth, and

the distribution of nutrients throughout the plant. Nitrogen helps stimulate leaf and stem growth, leading to more leaves and thicker stems, which increase overall biomass [5].

Leaf compost also provides nitrogen, phosphorus, and potassium that enhance vegetative tissue formation and biomass accumulation. Nitrogen improves chlorophyll production and photosynthesis, phosphorus supports energy metabolism, and potassium strengthens plant tissues and helps move nutrients, resulting in higher fresh plant weight [1].

Conclusion

The application of liquid organic fertilizer from vegetable waste and leaf compost was proven to have a highly significant effect on increasing plant height, number of fruits, stem diameter, and fresh weight. Therefore, it can serve as an effective and environmentally friendly organic fertilizer alternative.

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