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# The Effect of Liquid Organic Fertilizer Derived from Mustard Green Vegetable Waste on the Growth of Cayenne Pepper Plants (*Capsicum frutescens*)

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**Abstract**

Organic fertilizer is a type of fertilizer produced from natural materials derived from living organisms. One form of organic fertilizer is liquid organic fertilizer, which has the advantage of providing nutrients that are more readily available and easily absorbed by plants. This study aimed to analyze the effect of different concentrations of liquid organic fertilizer derived from mustard green vegetable waste on the growth of cayenne pepper plants (*Capsicum frutescens* L.). The study employed a Completely Randomized Design (CRD) consisting of five treatment levels: P0 (control), P1 5% (10 mL), P2 10% (20 mL), P3 15% (30 mL), and P4 20% (40 mL). Each treatment was replicated three times, resulting in a total of 15 experimental units. The observed parameters included plant height, stem diameter, and number of leaves. Data were analyzed statistically using Analysis of Variance (ANOVA), followed by the Least Significant Difference (LSD) test when significant differences were detected. The results showed that the application of liquid organic fertilizer derived from mustard green vegetable waste had a significant effect on plant height, stem diameter, and leaf number of cayenne pepper plants. Treatment P2 with a concentration of 10% (20 mL) produced the best results across all observed parameters. This finding indicates that this concentration was able to provide sufficient and balanced nutrients to support vegetative plant growth, whereas increasing the concentration to 15% and 20% did not result in a significant improvement in growth. Therefore, liquid organic fertilizer derived from mustard green vegetable waste has the potential to be utilized as an alternative organic fertilizer for enhancing the growth of cayenne pepper plants, with an optimum concentration of 10% (20 mL).

**Keywords:** *Capsicum frutescens*; mustard green waste; liquid organic fertilizer; plant growth.

## INTRODUCTION

Organic fertilizer is a type of fertilizer produced from natural materials derived from living organisms. One form of organic fertilizer is liquid organic fertilizer, which offers the advantage of providing nutrients that are more readily available and easily absorbed by plants. Liquid organic fertilizer is produced through the decomposition of organic materials originating from plant residues, animal manure, or human waste, and contains more than one essential nutrient element (Prasetyo & Evizal, 2021). This fertilizer can be applied directly to the root zone or sprayed onto plant stems and foliage (Sepriyaningsih et al., 2019). Among the various sources of liquid organic fertilizer, vegetable waste represents a promising and environmentally friendly alternative. Waste refers to residual materials that are no longer utilized and may cause negative environmental impacts, including water, soil, and air pollution, as well as unpleasant odors when not properly managed (Faizah et al., 2021). One type of vegetable waste that can be utilized as a raw material for liquid organic fertilizer production is mustard green waste, as mustard greens are widely cultivated and commonly consumed. This is supported by observations in local markets, which indicate that large quantities of mustard green waste are still generated and have not been utilized optimally.

At present, the agricultural sector is highly dependent on the use of chemical inputs and pesticides, which are commonly applied to fertilize crops, stimulate plant growth, and control pests, diseases, and weeds. However, excessive and uncontrolled use of pesticides can lead to adverse effects, particularly on human health and the environment (Jamin et al., 2024). Despite these risks, many farmers, including cayenne pepper growers, continue to apply pesticides excessively. This practice can reduce soil fertility, contribute to environmental pollution, and increase dependence on chemical products whose prices continue to rise. According to data from the Indonesian Central Statistics Agency (Badan Pusat

Statistik), cayenne pepper production in Central Sulawesi from 2022 to 2024 exhibited an unstable pattern characterized by fluctuations. Production reached approximately 253,887 quintals in 2022, decreased to 215,521.49 quintals in 2023, and then increased to 229,567.57 quintals in 2024. One of the factors contributing to these fluctuations is the implementation of inappropriate cultivation practices. This condition indicates that cultivation techniques, including fertilizer management, have not yet been optimized (Damayanti et al., 2023).

Cayenne pepper can grow and produce fruit optimally when cultivated under suitable environmental conditions, including favorable climate and soil characteristics. The ideal soil for its growth is loose, fertile, well-drained (porous), and rich in humus or organic matter (Aziez et al., 2021). To ensure that the growing medium contains sufficient nutrients, fertilization is necessary. Fertilizers provide additional nutrients to the soil, thereby supporting plant growth and development. Therefore, as an alternative to the extensive use of inorganic fertilizers, organic fertilizers should be considered. In this study, the organic fertilizer used was liquid organic fertilizer derived from mustard green vegetable waste. According to Riyati et al. (2022), mustard greens contain various nutrients required for plant growth, including 38 mg of phosphorus, 2.9 mg of iron, 220 mg of calcium, and 102 mg of L-ascorbic acid per 100 g of mustard green waste. The presence of these essential nutrients, combined with the abundant availability of mustard green waste, makes it a promising raw material for the production of liquid organic fertilizer (Jamin et al., 2024). This study aimed to analyze the effect of different concentrations of liquid organic fertilizer derived from mustard green vegetable waste on the growth of cayenne pepper plants (*Capsicum frutescens* L.).

## MATERIALS AND METHODS

### Study area

Mustard green vegetable waste was collected from Manonda Inpres Market, located on Jl. Kenduri Lrg. 1, Balaroa, Palu City. Meanwhile, the cultivation and maintenance of cayenne pepper seedlings were conducted at the Greenhouse of the Biology Laboratory, Faculty of Teacher Training and Education, Universitas Tadulako (Figure 1). The study was carried out over a three-month period, from February to April 2026.

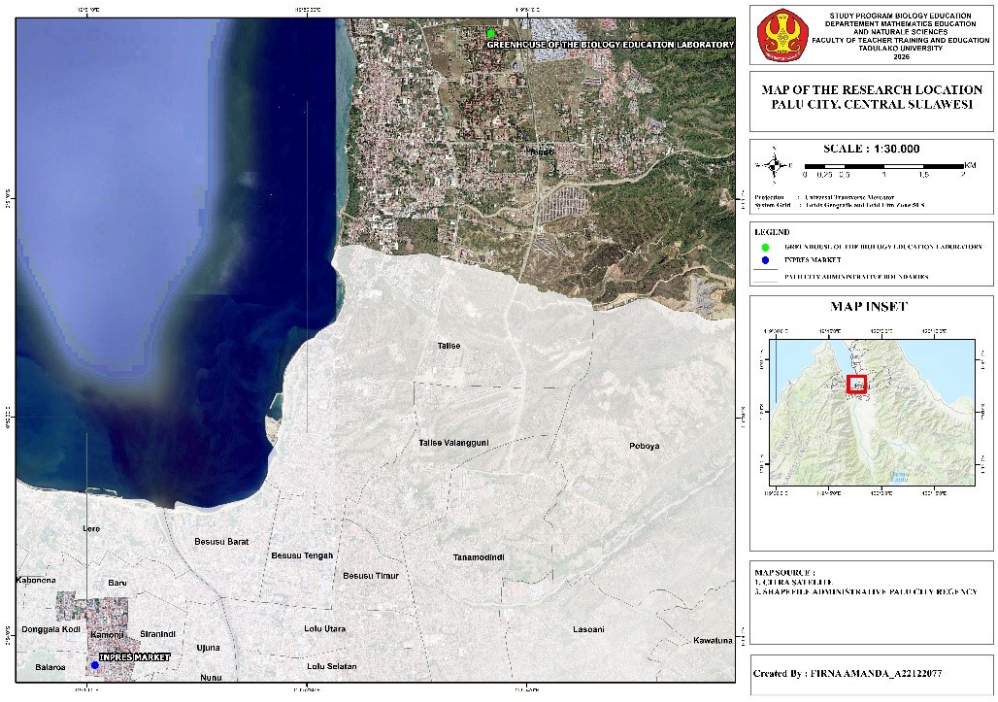


**Figure 1.** Map of the research location in Manonda Inpres Market, Balaroa, Palu City.

### Prosedures

*Preparation of Liquid Organic Fertilizer from Mustard Green Waste*

The preparation of liquid organic fertilizer (LOF) involved several stages, beginning with the activation of the EM4 microbial solution. Approximately 250 g of palm sugar was dissolved in 1 L of water. The sugar solution was then mixed with 3 L of well water, followed by the addition of approximately 250 mL of EM4 solution. The mixture was stirred thoroughly and allowed to stand for 1–2 days in a shaded area to ensure optimal microbial activation. The liquid organic fertilizer was subsequently prepared using a 15-L container. A total of 3 kg of mustard green vegetable waste was finely

chopped to accelerate the fermentation process and placed into the container. Five liters of clean water or well water (tap water was avoided due to its disinfectant content) and 1 L of rice-washing water were added. The previously activated EM4 solution was then incorporated into the mixture. All ingredients were thoroughly mixed until homogeneous. The container was tightly sealed and stored in a shaded location protected from direct sunlight for approximately two weeks. During the fermentation period, the container was opened every three days, and the mixture was stirred to facilitate the decomposition of organic matter. Successful fermentation was indicated by the production of a fermented aroma similar to that of traditional fermented cassava ("tape"), suggesting that the process had reached maturity. The resulting mixture was filtered to separate the liquid from the solid residue, and the liquid fertilizer was subsequently stored in clean bottles until use (Mauliani et al., 2022; Sitanggang et al., 2022).

*Preparation of Growing Media*

The growing medium consisted of a mixture of soil and goat manure at a ratio of 2:1. This composition has been reported as a suitable growing medium for plant cultivation (Long et al., 2021). The materials were mixed thoroughly using a hoe until a homogeneous mixture was obtained. Prior to filling the polybags, the soil was cleaned of debris and weeds to improve its texture and ensure a loose growing medium. The prepared medium was then placed into 4-kg polybags. Each polybag was labeled according to the treatment and arranged at a spacing of 30 cm × 30 cm following a previously randomized experimental layout.

*Seed Germination*

Seeds were germinated by soaking them in warm water for 12 hours to accelerate germination and reduce the risk of disease infection. Floating seeds were discarded because they were generally considered to be of lower quality. The submerged seeds were then evenly sown in germination polybags and lightly covered with the growing medium. The germination process was conducted for two weeks.

*Transplanting*

Seedlings were transplanted in the afternoon to avoid excessive exposure to sunlight, which could cause wilting. Transplanting was carried out when the cayenne pepper seedlings were two weeks old and exhibited relatively uniform growth, characterized by similar plant height and the presence of four to five leaves. Seedlings were transferred individually into prepared polybags. Planting holes approximately 1 cm deep were made in the growing medium, after which the seedlings were placed into the holes and covered with soil. One seedling was planted in each polybag.

*Plant Maintenance*

Plant maintenance included watering, weeding, and the application of liquid organic fertilizer. During the early growth stage, watering was carried out twice daily, in the morning and afternoon, using buckets and dippers. Thereafter, watering was reduced to once daily, either in the morning or afternoon. Adequate water availability throughout the growth period was essential for maintaining plant health and supporting productivity. Weeding was performed regularly to control weeds growing inside the polybags and around the planting area. Weed control was necessary because weeds compete with crop plants for nutrients, water, sunlight, and growing space. Weeds were removed manually by hand. Liquid organic fertilizer derived from mustard green vegetable waste was applied directly to the growing medium according to the following treatments: P0 (control, without liquid organic fertilizer), P1 (5% concentration or 10 mL), P2 (10% concentration or 20 mL), P3 (15% concentration or 30 mL), and P4 (20% concentration or 40 mL). Yunita et al. (2016) reported that liquid organic fertilizer produced from vegetable waste at concentrations ranging from 8% to 10% is highly effective in promoting growth and increasing the yield of chili plants. Fertilizer application commenced seven days after transplanting (DAT) and was repeated every 14 days, specifically at 7, 21, and 35 DAT.

*Data Collection*

Data were collected through direct observation of the experimental plants to evaluate the response of cayenne pepper to the application of liquid organic fertilizer derived from mustard green vegetable waste. The observed parameters included plant height, number of leaves, and stem diameter. Plant height was measured in centimeters (cm) from the base of the stem to the highest growing point. The number of leaves was determined by counting all fully formed leaves on each plant. Stem diameter was measured on the main stem at a predetermined marked position using a digital caliper. All parameters were recorded when the plants were 15, 30, and 45 days after transplanting (DAT).

**Data Analysis**

The collected data were analyzed using Analysis of Variance (ANOVA) with the aid of SPSS software to evaluate the effects of different concentrations of liquid organic fertilizer derived from mustard green vegetable waste on the growth of cayenne pepper (*Capsicum frutescens* L.). The analysis was conducted at a significance level of 5% ($\alpha = 0.05$). Treatment effects were considered significant when the calculated F-value ($F$calculated) was greater than the critical F-value ($F$table), resulting in the rejection of the null hypothesis ($H_0$). When ANOVA indicated significant differences among treatments, a Least Significant Difference (LSD) test was performed to identify differences between treatment means. This statistical approach was used to

assess variations in plant height, stem diameter, and leaf number among the treatment groups.

## RESULT AND DISCUSSION

### Plant Height of Cayenne Pepper

The application of liquid organic fertilizer derived from mustard green vegetable waste influenced the growth of cayenne pepper plants, particularly in terms of plant height. Plant height is one of the most important indicators of vegetative growth because it reflects the plant's ability to absorb and utilize available nutrients for cell division and elongation. The nutrients supplied through liquid organic fertilizer may contribute to improved metabolic processes, thereby supporting stem growth and overall plant development. Differences in plant height among treatments were observed throughout the experimental period, indicating varying responses of cayenne pepper plants to the different fertilizer concentrations applied (Figure 2).

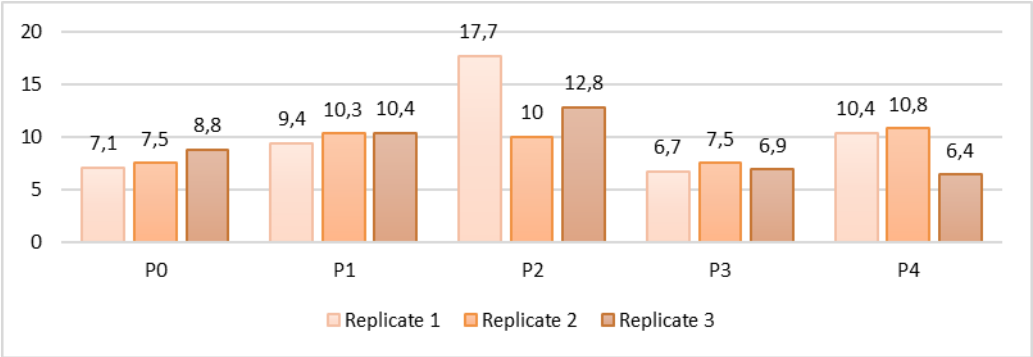


**Figure 2.** Average plant height growth of cayenne pepper (*Capsicum frutescens* L.) under different concentrations of liquid organic fertilizer (LOF) derived from mustard green vegetable waste. Each treatment was replicated three times (Replicates 1, 2, and 3). The treatments consisted of P0 = control (without LOF application), P1 = 10 mL LOF, P2 = 20 mL LOF, P3 = 30 mL LOF, and P4 = 40 mL LOF derived from mustard green vegetable waste.

Based on Figure 2, the average height of cayenne pepper plants in each treatment showed differences in growth among the replicates. In treatment P0 (control), plant height in the first replicate was 7.1 cm, increasing to 7.5 cm in the second replicate and 8.8 cm in the third replicate. In treatment P1 (10 mL of liquid organic fertilizer derived from mustard green vegetable waste), plant height reached 9.4 cm, 10.3 cm, and 10.4 cm in the first, second, and third replicates, respectively. Meanwhile, treatment P2 (20 mL of liquid organic fertilizer derived from mustard green vegetable waste) produced the greatest plant height compared to the other treatments, with heights of 17.7 cm in the first replicate, 10.0 cm in the second replicate, and 12.8 cm in the third replicate. In treatment P3 (30 mL of liquid organic fertilizer derived from mustard green vegetable waste), plant height was relatively lower, measuring 6.7 cm, 7.5 cm, and 6.9 cm in the first, second, and third replicates, respectively. Treatment P4 (40 mL of liquid organic fertilizer derived from mustard green vegetable waste) showed plant heights of 10.4 cm in the first replicate, increasing to 10.8 cm in the second replicate, but decreasing to 6.4 cm in the third replicate. Based on the average plant height of cayenne pepper in each treatment, differences in growth values were observed among the applied liquid organic fertilizer doses. However, these average differences could not yet indicate a significant effect of liquid organic fertilizer derived from mustard green vegetable waste on plant height growth. Therefore, an Analysis of Variance (ANOVA) was conducted to determine whether the differences in average plant height among treatments were statistically significant or merely caused by variation among replicates (Table 1).

**Table 1.** Analysis of Variance (ANOVA) results for plant height of cayenne pepper in response to the application of liquid organic fertilizer derived from mustard green vegetable waste at 15, 30, and 45 days after transplanting (DAT).

| | Sum of Squares | df | Mean Square | F | Sig.[a] |
|---|---|---|---|---|---|
| Between Groups | 76.044 | 4 | 19.011 | 4.248 | .029 |
| Within Groups | 44.753 | 10 | 4.475 | | |
| Total | 120.797 | 14 | | | |

Note: Treatment effects were considered significant when the significance value (Sig.) was less than 0.05 (Sig. < 0.05).

The results of the Analysis of Variance (ANOVA) showed that the application of liquid organic fertilizer (LOF) derived from mustard green vegetable waste had a significant effect on the height of cayenne pepper plants.

This was indicated by an F-value of 4.248 and a significance value (Sig.) of 0.029 (< 0.05), resulting in the rejection of the null hypothesis ($H_0$) and acceptance of the alternative hypothesis ($H_1$). Therefore, it can be concluded that the different concentrations of liquid organic fertilizer derived from mustard green vegetable waste significantly affected the height growth of cayenne pepper plants. Since the ANOVA results indicated a significant difference among treatments, a Least Significant Difference (LSD) test was subsequently conducted at the 5% significance level (Table 2).

**Table 2.** Least Significant Difference (LSD) test for plant height of cayenne pepper in response to different concentrations of liquid organic fertilizer derived from mustard green vegetable waste.

| (I) Treatment | (J) Treatment | Mean Difference (I-J) | Std. Error | Sig. | 95%Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| P0 | P1 | -2.23333 | 1.72730 | .225 | -6.0820 | 1.6153 |
| | P2 | -5.70000* | 1.72730 | .008 | -9.5487 | -1.8513 |
| | P3 | .76667 | 1.72730 | .667 | -3.0820 | 4.6153 |
| | P4 | -1.40000 | 1.72730 | .437 | -5.2487 | 2.4487 |
| P1 | P0 | 2.23333 | 1.72730 | .225 | -1.6153 | 6.0820 |
| | P2 | -3.46667 | 1.72730 | .073 | -7.3153 | .3820 |
| | P3 | 3.00000 | 1.72730 | .113 | -.8487 | 6.8487 |
| | P4 | .83333 | 1.72730 | .640 | -3.0153 | 4.6820 |
| P2 | P0 | 5.70000* | 1.72730 | .008 | 1.8513 | 9.5487 |
| | P1 | 3.46667 | 1.72730 | .073 | -.3820 | 7.3153 |
| | P3 | 6.46667* | 1.72730 | .004 | 2.6180 | 10.3153 |
| | P4 | 4.30000* | 1.72730 | .032 | .4513 | 8.1487 |
| P3 | P0 | -.76667 | 1.72730 | .667 | -4.6153 | 3.0820 |
| | P1 | -3.00000 | 1.72730 | .113 | -6.8487 | .8487 |
| | P2 | -6.46667* | 1.72730 | .004 | -10.3153 | -2.6180 |
| | P4 | -2.16667 | 1.72730 | .238 | -6.0153 | 1.6820 |
| P4 | P0 | 1.40000 | 1.72730 | .437 | -2.4487 | 5.2487 |
| | P1 | -.83333 | 1.72730 | .640 | -4.6820 | 3.0153 |
| | P2 | -4.30000* | 1.72730 | .032 | -8.1487 | -.4513 |
| | P3 | 2.16667 | 1.72730 | .238 | -1.6820 | 6.0153 |

*.The mean difference is significant at the 0.05 level.

The results of the LSD test showed that treatment P2 differed significantly from treatments P0, P3, and P4, but did not differ significantly from P1. Meanwhile, treatment P0 did not differ significantly from P1, P3, and P4. Likewise, treatments P1, P3, and P4 were not significantly different from one another. These results indicate that treatment P2 produced the best response in terms of plant height growth, whereas treatments P0, P1, P3, and P4 showed relatively similar responses in plant height growth.

**Stem Diameter of Cayenne Pepper Plants**

The application of liquid organic fertilizer derived from mustard green vegetable waste also influenced the stem diameter growth of cayenne pepper plants. Stem diameter is an important vegetative growth parameter because it reflects the plant's structural strength and its ability to support the transport of water and nutrients from the roots to other plant organs. An increase in stem diameter generally indicates improved plant growth and development resulting from adequate nutrient availability. Differences in stem diameter growth were observed among the treatments, suggesting that the various concentrations of liquid organic fertilizer affected the growth response of cayenne pepper plants to different extents (Figure 3).

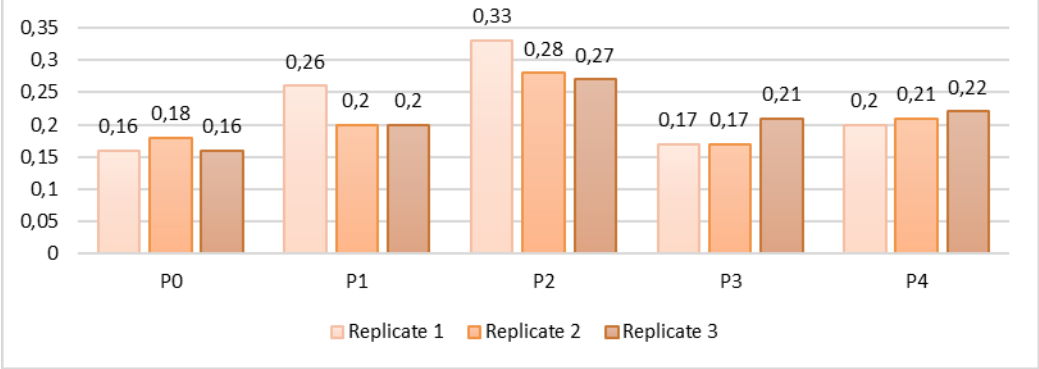

**Figure 3.** Average stem diameter of cayenne pepper plants in Replicates 1, 2, and 3.

Based on Figure 3, the average stem diameter of cayenne pepper plants in each treatment showed differences in growth among the replicates. In treatment P0 (control), the stem diameter in the first replicate was 0.16 cm, increased to 0.18 cm in the second replicate, and then decreased to 0.16 cm in the third replicate. In treatment P1 (10 mL of liquid organic fertilizer derived from mustard green vegetable waste), the stem diameter reached 0.26 cm in the first replicate, while the second and third replicates each recorded a diameter of 0.20 cm. Treatment P2 (20 mL of liquid organic fertilizer derived from mustard green vegetable waste) produced the largest stem diameter compared to the other treatments, with values of 0.32 cm in the first replicate, 0.28 cm in the second replicate, and 0.27 cm in the third replicate. Meanwhile, in treatment P3 (30 mL of liquid organic fertilizer derived from mustard green vegetable waste), stem diameter was 0.17 cm in both the first and second replicates and increased to 0.21 cm in the third replicate. In treatment P4 (40 mL of liquid organic fertilizer derived from mustard green vegetable waste), stem diameter was 0.20 cm in the first replicate, 0.21 cm in the second replicate, and 0.22 cm in the third replicate. Based on these averages, treatment P2 (20 mL of liquid organic fertilizer derived from mustard green vegetable waste) showed a larger stem diameter than the other treatments, whereas treatments P0 (control) and P3 (30 mL) tended to produce smaller stem diameters. However, the differences in average stem diameter among treatments shown in Figure 3 cannot yet be used as evidence of a significant effect of liquid organic fertilizer derived from mustard green vegetable waste. Therefore, an Analysis of Variance (ANOVA) was conducted at a 5% significance level to determine whether the observed differences in average stem diameter were statistically significant.

**Table 3.** Analysis of Variance (ANOVA) results for stem diameter of cayenne pepper in response to the application of liquid organic fertilizer derived from mustard green vegetable waste at 15, 30, and 45 days after transplanting (DAT).

| | Sum of Squares | df | Mean Square | F | Sig.[a] |
|---|---|---|---|---|---|
| Between Groups | .029 | 4 | .007 | 11.906 | .001 |
| Within Groups | .006 | 10 | .001 | | |
| Total | .035 | 14 | | | |

Note: Treatment effects were considered significant when the significance value (Sig.) was less than 0.05 (Sig. < 0.05).

Based on the results of the Analysis of Variance (ANOVA), the treatments had a highly significant effect on the stem diameter of cayenne pepper plants. This was indicated by an F-value of 11.906 and a significance value (Sig. < 0.001), which was lower than the 5% significance level ($\alpha = 0.05$). Therefore, the null hypothesis ($H_0$), which stated that the application of liquid organic fertilizer derived from mustard green vegetable waste had no effect on the stem diameter of cayenne pepper (*Capsicum frutescens* L.), was rejected, while the alternative hypothesis ($H_1$) was accepted. These results indicate that the applied treatments were able to influence the vegetative growth of the plants, particularly in terms of stem diameter. Consequently, a Least Significant Difference (LSD) test was conducted to determine the differences among treatments.

**Table 4.** Results of the Least Significant Difference (LSD) test for stem diameter of cayenne pepper in response to different concentrations of liquid organic fertilizer derived from mustard green vegetable waste.

| (I) Treatment | (J) Treatment | Mean Difference (I-J) | Std. Error | Sig. | 95%Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| P0 | P1 | -.05333* | .02000 | .024 | -.0979 | -.0088 |
| | P2 | -.12667* | .02000 | <.001 | -.1712 | -.0821 |
| | P3 | -.01667 | .02000 | .424 | -.0612 | .0279 |
| | P4 | -.04333 | .02000 | .055 | -.0879 | .0012 |
| P1 | P0 | .05333* | .02000 | .024 | .0088 | .0979 |
| | P2 | -.07333* | .02000 | .004 | -.1179 | -.0288 |
| | P3 | .03667 | .02000 | .097 | -.0079 | .0812 |
| | P4 | .01000 | .02000 | .628 | -.0346 | .0546 |
| P2 | P0 | .12667* | .02000 | <.001 | .0821 | .1712 |
| | P1 | .07333* | .02000 | .004 | .0288 | .1179 |
| | P3 | .11000* | .02000 | <.001 | .0654 | .1546 |
| | P4 | .08333* | .02000 | .002 | .0388 | .1279 |
| P3 | P0 | .01667 | .02000 | .424 | -.0279 | .0612 |
| | P1 | -.03667 | .02000 | .097 | -.0812 | .0079 |

| (I) Treatment | (J) Treatment | Mean Difference (I-J) | Std. Error | Sig. | 95%Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| P4 | P2 | -.11000* | .02000 | <.001 | -.1546 | -.0654 |
| | P4 | -.02667 | .02000 | .212 | -.0712 | .0179 |
| | P0 | .04333 | .02000 | .055 | -.0012 | .0879 |
| | P1 | -.01000 | .02000 | .628 | -.0546 | .0346 |
| | P2 | -.08333* | .02000 | .002 | -.1279 | -.0388 |
| | P3 | .02667 | .02000 | .212 | -.0179 | .0712 |

*. The mean difference is significant at the 0.05 level.

The results of the LSD test at the 5% significance level showed that treatment P2 differed significantly from all other treatments, namely P0, P1, P3, and P4. This indicates that treatment P2 produced the most distinct response in terms of stem diameter growth compared to the other treatments. Meanwhile, treatment P0 did not differ significantly from P3 and P4 but differed significantly from P1 and P2. Treatment P1 did not differ significantly from P3 and P4; however, it differed significantly from P0 and P2. Treatment P3 also did not differ significantly from P0, P1, and P4 but differed significantly from P2. Similarly, treatment P4 did not differ significantly from P0, P1, and P3 but differed significantly from P2. These results indicate that most treatments produced relatively similar growth responses, except for treatment P2, which exhibited the best response among all treatments.

**Number of Leaves of Cayenne Pepper Plants**

The application of liquid organic fertilizer derived from mustard green vegetable waste influenced the number of leaves produced by cayenne pepper plants. Leaf number is one of the important indicators of vegetative growth because leaves play a crucial role in the photosynthetic process, which supports plant growth and development. An increase in leaf number generally reflects favorable growing conditions and adequate nutrient availability for plant metabolism. Differences in leaf production among the treatments were observed throughout the experimental period, indicating that the various concentrations of liquid organic fertilizer affected the growth response of cayenne pepper plants to different degrees (Figure 4).

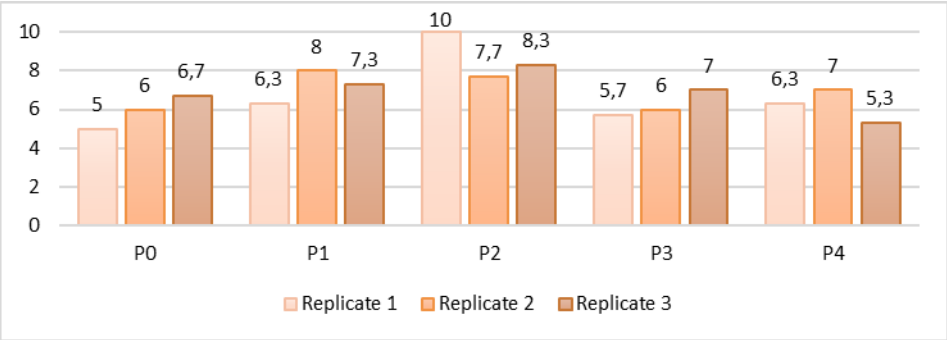


**Figure 4.** Average number of leaves of cayenne pepper plants in Replicates 1, 2, and 3.

Based on Figure 4, the average number of leaves of cayenne pepper plants varied among treatments and replicates. In treatment P0 (control), the average number of leaves was 5.0 in the first replicate, 6.0 in the second replicate, and 6.7 in the third replicate. Treatment P1 (10 mL of liquid organic fertilizer derived from mustard green vegetable waste) produced an average of 6.3 leaves in the first replicate, increasing to 8.0 leaves in the second replicate and slightly decreasing to 7.3 leaves in the third replicate. In treatment P2 (20 mL of liquid organic fertilizer derived from mustard green vegetable waste), the average number of leaves reached 10.0 in the first replicate, 7.7 in the second replicate, and 8.3 in the third replicate. Meanwhile, treatment P3 (30 mL of liquid organic fertilizer derived from mustard green vegetable waste) resulted in an average of 5.7 leaves in the first replicate, 6.0 leaves in the second replicate, and increased to 7.0 leaves in the third replicate. In treatment P4 (40 mL of liquid organic fertilizer derived from mustard green vegetable waste), the average number of leaves was 6.3 in the first replicate, increased to 7.0 in the second replicate, and then decreased to 5.3 in the third replicate. In general, treatment P2 (20 mL of liquid organic fertilizer derived from mustard green vegetable waste) tended to produce a higher average number of leaves than the other treatments, whereas treatment P0 (control) showed relatively lower values. To determine whether the differences in the average number of leaves among treatments were influenced by the application of liquid organic fertilizer derived from mustard green vegetable waste, an Analysis of Variance (ANOVA) was conducted.

**Table 5.** Analysis of Variance (ANOVA) results for the number of leaves of cayenne pepper in response to the application of liquid organic fertilizer derived from mustard green vegetable waste at 15, 30, and 45 days after transplanting (DAT).

| | Sum of Squares | df | Mean Square | F | Sig.[a] |
|---|---|---|---|---|---|
| Between Groups | 14.664 | 4 | 3.666 | 3.837 | .038 |
| Within Groups | 9.553 | 10 | .955 | | |
| Total | 24.217 | 14 | | | |

Note: Treatment effects were considered significant when the significance value (Sig.) was less than 0.05 (Sig. < 0.05).

Based on the results of the Analysis of Variance (ANOVA), the application of liquid organic fertilizer (LOF) derived from mustard green vegetable waste had a significant effect on the number of leaves of cayenne pepper plants. This was indicated by an F-value of 3.837 and a significance value (Sig. < 0.038), which was lower than the 5% significance level ($\alpha = 0.05$). Therefore, the null hypothesis ($H_0$) was rejected and the alternative hypothesis ($H_1$) was accepted, indicating that the treatments significantly affected leaf formation in cayenne pepper plants. Since the ANOVA results revealed a significant treatment effect, a Least Significant Difference (LSD) test was subsequently conducted at the 5% significance level.

**Table 6.** Least Significant Difference (LSD) test for the number of leaves of cayenne pepper in response to different concentrations of liquid organic fertilizer derived from mustard green vegetable waste.

| (I) Treatment | (J) Treatment | Mean Difference (I-J) | Std. Error | Sig. | 95%Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| P0 | P1 | -1.30000 | .79805 | .134 | -3.0782 | .4782 |
| | P2 | -2.76667* | .79805 | .006 | -4.5448 | -.9885 |
| | P3 | -.56667 | .79805 | .494 | -2.3448 | 1.2115 |
| | P4 | -.30000 | .79805 | .715 | -2.0782 | 1.4782 |
| P1 | P0 | 1.30000 | .79805 | .134 | -.4782 | 3.0782 |
| | P2 | -1.46667 | .79805 | .096 | -3.2448 | .3115 |
| | P3 | .73333 | .79805 | .380 | -1.0448 | 2.5115 |
| | P4 | 1.00000 | .79805 | .238 | -.7782 | 2.7782 |
| P2 | P0 | 2.76667* | .79805 | .006 | .9885 | 4.5448 |
| | P1 | 1.46667 | .79805 | .096 | -.3115 | 3.2448 |
| | P3 | 2.20000* | .79805 | .020 | .4218 | 3.9782 |
| | P4 | 2.46667* | .79805 | .011 | .6885 | 4.2448 |
| P3 | P0 | .56667 | .79805 | .494 | -1.2115 | 2.3448 |
| | P1 | -.73333 | .79805 | .380 | -2.5115 | 1.0448 |
| | P2 | -2.20000* | .79805 | .020 | -3.9782 | -.4218 |
| | P4 | .26667 | .79805 | .745 | -1.5115 | 2.0448 |
| P4 | P0 | .30000 | .79805 | .715 | -1.4782 | 2.0782 |
| | P1 | -1.00000 | .79805 | .239 | -2.7782 | .7782 |
| | P2 | -2.46667* | .79805 | .011 | -4.2448 | -.6885 |
| | P3 | -.26667 | .79805 | .745 | -2.0448 | 1.5115 |

*. The mean difference is significant at the 0.05 level.

The results of the LSD test showed that treatment P2 differed significantly from treatments P0, P3, and P4, but did not differ significantly from P1. Meanwhile, treatments P0, P1, P3, and P4 did not show significant differences from one another. These results indicate that treatment P2 produced the best response in terms of leaf formation in cayenne pepper plants.

## Discussion

Based on the results of the ANOVA and Least Significant Difference (LSD) tests, the application of liquid organic fertilizer (LOF) derived from mustard green vegetable waste had a significant effect on the height growth of cayenne pepper plants, with treatment P2 producing the greatest plant height. This result is presumably due to the ability of the applied fertilizer concentration to provide sufficient and balanced amounts of essential nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), thereby supporting optimal vegetative growth. Nitrogen plays an important role in promoting plant growth, chlorophyll formation, protein synthesis, growth acceleration, and the activation of meristematic cells in the stem, which enhances cell division and elongation. Phosphorus functions in energy transfer during metabolic processes and stimulates root development, flowering, and fruit formation, while potassium contributes to photosynthesis, translocation of assimilates, enzyme activation, and the regulation of mineral and water balance within plant tissues

(Driantama et al., 2021). The combined availability of these nutrients improves metabolic efficiency, resulting in enhanced vegetative growth and allowing plants to attain greater height compared with other treatments. The LSD test further revealed that treatment P2, with a concentration of 10% (20 mL), produced the best plant height, whereas increasing the concentration to 15% (30 mL) and 20% (40 mL) did not result in a significant increase in plant height. These findings are consistent with those reported by Yunita et al. (2016), who found that the application of liquid organic fertilizer had a highly significant effect on chili plant height, with a concentration of 10% (20 mL) producing the best growth response compared with other treatments. This finding suggests that the application of liquid organic fertilizer at an optimum concentration can enhance vegetative growth by increasing the availability of nutrients that are readily absorbed by plants. Furthermore, Buana et al. (2025) reported that liquid organic fertilizer derived from mustard green waste had a highly significant effect on plant height compared with liquid organic fertilizers produced from household waste and banana peel waste. This superior performance was attributed to the higher nitrogen content of mustard green waste-based fertilizer, which more effectively supports vegetative plant growth.

The application of liquid organic fertilizer (LOF) derived from mustard green vegetable waste also had a significant effect on the stem diameter development of cayenne pepper plants. Stem diameter is an important indicator of vegetative growth because it reflects the plant's ability to develop vascular tissues responsible for transporting water, nutrients, and photosynthetic products throughout the plant. Therefore, better stem diameter development generally indicates a greater capacity to support the growth of other vegetative organs. Nitrogen (N) contained in mustard green vegetable waste plays a crucial role in stimulating vegetative growth, particularly the development of stems and leaves, thereby supporting the photosynthetic process (Abror & Indra Kurniawan, 2025). Adequate nutrient availability enhances plant metabolic activity, resulting in more optimal stem tissue formation. In contrast, when nutrient availability is insufficient or nutrients cannot be absorbed efficiently by the plant, stem diameter growth tends to be reduced. Based on the results of the LSD test, treatment P2 with a concentration of 10% (20 mL) produced the greatest stem diameter development. However, increasing the LOF concentration to 15% (30 mL) and 20% (40 mL) did not result in a significant increase in stem diameter. This finding indicates that applying liquid organic fertilizer beyond the plant's nutritional requirements does not necessarily promote additional growth. According to Driantama et al. (2021) excessively high concentrations of liquid organic fertilizer may increase soil acidity, thereby reducing the efficiency of nutrient uptake by plant roots. As a result, plant metabolic processes become less efficient, and stem diameter growth is not optimized despite the higher fertilizer concentration. Therefore, a concentration of 10% (20 mL) can be considered the most effective dosage for enhancing stem diameter growth in cayenne pepper plants.

The application of liquid organic fertilizer (LOF) derived from mustard green vegetable waste also had a significant effect on the number of leaves of cayenne pepper plants. Based on the results of the LSD test, treatment P2 with a concentration of 10% (20 mL) produced the highest number of leaves and differed significantly from treatments P0, P3, and P4, but did not differ significantly from P1. These results indicate that treatment P2 was the most effective concentration for promoting leaf formation during the vegetative growth stage. The greater number of leaves observed in treatment P2 may be associated with the superior plant height achieved under this treatment compared with the others. Taller plants generally develop more stem internodes, which provide additional sites for the emergence of new leaves. This finding is consistent with Mauliani et al. (2022), who reported that plant height is positively related to leaf production, indicating that taller plants tend to produce a greater number of leaves. In addition, the increased leaf number in treatment P2 was likely influenced by the adequate availability of nitrogen (N). Nitrogen plays a key role in stimulating vegetative growth, including the development of leaves, stems, branches, and shoots, and contributes to chlorophyll synthesis, which is essential for photosynthesis (Driantama et al., 2021). The chlorophyll produced enhances the plant's ability to capture light energy, thereby improving photosynthetic efficiency. The resulting photosynthates are subsequently utilized to support cell division and differentiation, leading to the formation of new leaves (Sepriyaningsih et al., 2019). In addition to nitrogen, phosphorus (P) contained in the liquid organic fertilizer also plays an important role in leaf development. Phosphorus is an essential component of plant metabolism because it is involved in the formation of phosphate sugars required during photosynthesis (Nurfadilah A. et al., 2021). Therefore, the combined availability of nitrogen and phosphorus in treatment P2 likely created more favorable conditions for leaf formation than those provided by the other treatments. These findings are consistent with the study of Hanifa et al. (2022), which reported that the application of liquid organic fertilizer produced from rice-washing water and mustard green waste significantly increased the number of leaves in tomato plants. The study demonstrated that a 10% concentration resulted in the best vegetative growth because it supplied sufficient nutrients to support cell division and enlargement, particularly in stems and leaves.

## CONCLUSIONS

The application of liquid organic fertilizer (LOF) derived from mustard green vegetable waste had a significant

effect on the growth of cayenne pepper (*Capsicum frutescens* L.), as demonstrated by improvements in plant height, stem diameter, and leaf number. Among the treatments tested, P2 with a concentration of 10% (20 mL) produced the most optimal growth performance. Therefore, this treatment can be recommended as the most effective dosage for promoting the vegetative growth of cayenne pepper plants.

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