



## Effect of Liquid Organic Fertilizer Derived from Catfish Offal Waste and Banana Pseudostems on the Growth of Curly Chili Pepper (*Capsicum annuum* L. var. *longum*)

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**Abstract:** This study aimed to analyze the effect of liquid organic fertilizer (LOF) derived from catfish offal waste and banana stems on the vegetative growth of curly chili (*Capsicum annuum* L. var. *longum*). The study employed an experimental method using a randomized block design (RBD) with four treatments: P0 (control), P1 (20 mL LOF/L), P2 (40 mL LOF/L), and P3 (60 mL LOF/L), each with six replications. The LOF was applied at a rate of 200 mL per plant weekly. The observed parameters included plant height, leaf number, and leaf width over a four-week period, and the data were analyzed using one-way ANOVA followed by a post hoc test. The results showed that the LOF contained 0.08% N, 0.09% P, and 15.9 mg/L K, and had a significant effect on all measured parameters (Sig. < 0.05). Treatment P1 produced the best results, increasing plant height by 59.9%, leaf number by 43.2%, and leaf width by 21.2% compared with the control. The decline in growth at higher doses indicates the potential for phytotoxicity or nutrient imbalance. Therefore, this organic waste-based LOF was effective at low to moderate doses in enhancing the early vegetative growth of curly chili.

**Keywords:** Liquid organic fertilizer; fishery waste; banana stem; vegetative growth; *Capsicum annuum*

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### INTRODUCTION

Agriculture remains a major pillar of the economy in many countries, including Indonesia (Batubara & Pane, 2023). One of the principal challenges in agriculture is to increase crop yields while maintaining environmental sustainability (Sahala et al., 2024). The long-term use of chemical fertilizers is known to cause adverse effects on human health, contribute to water pollution, and degrade soil quality (Hidayah et al., 2022). These conditions highlight the need for more environmentally friendly and sustainable fertilization alternatives to support healthier and more productive agricultural systems.

One potential alternative to reduce dependence on chemical fertilizers is liquid organic fertilizer (POC) (Kusmutafmi et al., 2023). Because POC is produced from biodegradable organic materials, it is expected to improve soil fertility while reducing environmental pollution. In this context, research on POC derived from catfish (*Clarias batrachus*) viscera waste and banana (*Musa* sp.) pseudostems is highly relevant. Both types of waste are abundant and are often underutilized; therefore, converting them into POC could provide significant added value.

The use of organic waste as a raw material for POC also has the potential to address community waste management problems. In Balekencono Village, catfish farming for consumption is practiced, with each harvest yielding approximately 90–100 kg of catfish after a rearing period of about 2.5 months and a harvest frequency of approximately 4–5 times per year. This activity generates around 9–10 kg of viscera

waste per harvest, or approximately 36–50 kg of waste annually, which has not been optimally utilized. In addition, field observations indicate that around 360 households in the village have home yards planted with banana trees, whose pseudostems are generally left to decompose after harvest and are not used efficiently. These conditions demonstrate the potential of catfish viscera waste and banana pseudostems as raw materials for liquid organic fertilizer (POC) to support plant growth, particularly that of curly chili, a crop with high economic value. Fish viscera waste has the potential to be processed into POC because it contains 14.01% protein, 4.75% ash, and 1%–1.9% phosphorus. Banana pseudostems also have strong potential for use as organic fertilizer (Rohmawati et al., 2023). They contain 16% calcium, 23% potassium, and 32% phosphorus (Rohmawati et al., 2023). Both waste materials therefore have the potential to be processed into POC that may support the vegetative growth of curly chili plants. Curly chili was selected because it is a high-value crop, and its vegetative phase is critical in determining productivity and harvest quality.

A number of studies have shown that liquid organic fertilizer (POC) derived from organic waste can improve plant growth and yield. A study on the effect of POC produced from market organic waste on curly red chili of the Lado F1 variety found that a 50% POC dose increased plant productivity, resulting in 26.60 fruits with a total weight of 105.60 g (Putri et al., 2023). This finding demonstrates the effectiveness of POC as an environmentally friendly alternative fertilizer. Another study examined the fermentation of POC made from fish viscera waste and banana pseudostems using a bioactivator. The results showed relatively high nitrogen, phosphorus, and potassium contents that met the Indonesian National Standard (SNI) for liquid organic fertilizer, although the fermentation process was influenced by temperature, pH, and fermentation duration (Rohmawati et al., 2023). In addition, other research reported that the fermentation of fish viscera waste into liquid fertilizer effectively enhanced plant growth while reducing the negative environmental impacts associated with chemical fertilizer use (Mukmin et al., 2021).

Community outreach on the production of liquid organic fertilizer (POC) from fish and vegetable waste has also shown a positive public response and improved the quality of home-garden plants, although community participation in its implementation still needs to be strengthened (Juwita et al., 2023). Another study further demonstrated that POC application significantly affected both vegetative and generative growth of chili plants, particularly at specific concentrations (Pratiwi et al., 2021). Overall, the literature indicates that POC derived from organic waste has considerable potential as an environmentally friendly fertilizer. However, most previous studies have focused on the fermentation process, nutrient content, or the use of POC derived from a single type of waste material. Consequently, studies investigating the use of a mixture of catfish viscera waste and banana pseudostems, as well as its effect on the vegetative growth of curly chili plants, remain limited. Therefore, this study was conducted to examine the effect of POC prepared from a mixture of these two waste materials on the vegetative growth of curly chili plants, using plant height, leaf number, and leaf width as the study parameters.

From a scientific perspective, the use of a mixture of catfish viscera and banana pseudostems has the potential to produce a liquid organic fertilizer with a more balanced nutrient composition. Fish viscera are known to be rich in nitrogen, which plays an essential role in the formation of vegetative plant tissues, whereas banana pseudostems contain potassium and phosphorus, which contribute to plant vigor and cellular metabolism (Rohmawati et al., 2023). The combination of these two materials is therefore expected to provide complementary organic nutrients for plant growth.

This study aimed to evaluate the effect of liquid organic fertilizer (POC) produced from a mixture of catfish viscera waste and banana pseudostems on the vegetative growth of curly chili (*Capsicum annuum* L. var. *longum*), and to determine the most effective POC dose for supporting optimal plant growth. The growth response of curly chili was analyzed using vegetative growth indicators, namely plant height, leaf number, and leaf width. These indicators were selected because they reflect the plant's ability to absorb nutrients and carry out physiological growth processes. In this study, the POC variable was operationalized based on variations in the application dose of liquid organic fertilizer derived from the mixture of catfish viscera waste and banana pseudostems, with the aim of identifying the relationship between organic nutrient concentration and plant growth response. The findings of this study are expected to contribute to the development of science and technology in applied biology through the utilization of organic waste as an alternative environmentally friendly fertilizer.

From a practical perspective, the use of catfish viscera waste in Balekencono Village, which reaches approximately 36–50 kg per year, together with banana pseudostem waste from around 360 household yards, has the potential to reduce the accumulation of organic waste that has not been optimally utilized. Processing these wastes into liquid organic fertilizer may also help reduce the community's dependence on, and expenditure for, chemical fertilizers. Nevertheless, its implementation still faces several limitations, including the time required for fermentation and the need for fertilizer quality control, which is influenced by raw material composition and fermentation conditions.

## METHOD

This study employed a quantitative approach using an experimental method, as this approach enables researchers to control independent variables and directly observe the effects of treatments on dependent variables (Selvira & Albina, 2025). The experimental method was selected because it was considered the most appropriate for examining the causal relationship between the application of liquid organic fertilizer (LOF) and the growth of curly chili plants. The study used a Randomized Complete Block Design (RCBD) to minimize the influence of environmental factors that could not be fully controlled (Hidayat et al., 2025). In this study, blocking was based on differences in the positions of polybags within the planting area, which could potentially result in variation in the light intensity received by the plants. Therefore, each block was arranged according to similarity in plant placement, so that environmental variation could be reduced and treatment effects could be compared more objectively.

The experiment consisted of four treatments: P0 (control), P1 (20 mL LOF + 1 L water), P2 (40 mL LOF + 1 L water), and P3 (60 mL LOF + 1 L water). The LOF solution was prepared by mixing the fertilizer according to the treatment dose into 1 L of water, followed by homogenization before application. Fertilizer was applied by pouring 200 mL of the LOF solution onto the planting medium in each polybag. Fertilization was carried out once a week for four weeks during the observation period. Each treatment was replicated six times, resulting in a total of 24 experimental units. The dose range of 20 mL, 40 mL, and 60 mL was used as a concentration gradient to evaluate the growth response of curly chili plants to increasing LOF doses.

The subjects of this study were curly chili plants (*Capsicum annuum* L. var. *longum*), which served as the treatment objects. The study population comprised 32 chili plants aged 14 days after planting (DAP). From this population, 24 plants were selected as research samples. The sample size was determined according to the requirements of the RCBD experimental design used in this study. The sampling

technique applied was simple random sampling, meaning that each plant in the population had an equal opportunity to be selected as a sample without consideration of sequence or specific characteristics (Noor et al., 2022). The selection of plants at 14 DAP was based on the consideration that, at this stage, the plants had reached a relatively stable physiological condition and were ready to receive fertilization treatment.

All samples were placed in the same planting area with an overhead tarpaulin cover to reduce the direct effects of rainfall and excessive light intensity, thereby providing relatively uniform environmental conditions throughout the study period. The planting medium consisted of a 1:1 mixture of soil and mature goat manure. The uniformity of environmental conditions and sample characteristics was expected to ensure that any observed differences in plant growth were attributable to the applied LOF doses.

The research instruments consisted of plant growth measurement tools, including a ruler to measure plant height and leaf width, and an observation sheet to record the number of leaves. These instruments were selected because they were appropriate for the observed plant growth parameters and could be applied consistently. Measurements were conducted directly through visual observation and physical measurement of the plants.

The research procedure began with the preparation of liquid organic fertilizer from a 1:1 mixture of catfish viscera waste and banana stems through anaerobic fermentation for 2–3 weeks using EM4 as a decomposer. After fermentation was completed, the LOF was analyzed in the laboratory for its nitrogen (N), phosphorus (P), and potassium (K) contents. Chili seedlings were then raised in nursery conditions and transplanted into larger polybags at 14 DAP. The LOF treatment was applied according to the predetermined doses, whereas the control group received only water without additional fertilizer. This control treatment served as a comparison to assess differences in growth between plants treated with LOF and those receiving no fertilizer. Growth observations were conducted weekly for four weeks and included measurements of plant height, leaf number, and leaf width.

Data analysis was conducted quantitatively to interpret the effects of varying doses of liquid organic fertilizer on the growth of curly chili plants. The observed growth variables included plant height, number of leaves, and leaf width. Plant height was measured from the surface of the planting medium to the growing point of the plant, leaf number was determined by counting fully expanded leaves, and leaf width was measured at the widest part of the leaf using a ruler. Measurements were taken once a week for four weeks after treatment application.

Before hypothesis testing, the data were subjected to prerequisite tests for analysis. Normality was assessed using the Shapiro–Wilk test because the sample size was fewer than 50, with data considered normally distributed when the significance value was greater than 0.05 (Sianturi, 2025). Homogeneity of variance was then tested using Levene's test to confirm the uniformity of variance across treatment groups (Nurhaswinda et al., 2026). If the data met the assumptions of normality and homogeneity, the analysis proceeded with a one-way ANOVA to determine differences in the effects among LOF dose treatments. The null hypothesis ( $H_0$ ) stated that there was no significant difference among treatments, whereas the alternative hypothesis ( $H_1$ ) stated that treatment effects differed significantly with respect to plant growth. Decisions were made based on the significance value at a 95% confidence level ( $\alpha = 0.05$ ) (Ross & Willson, 2017). When the ANOVA results indicated a significant difference, Tukey's Honestly Significant Difference (HSD) post

hoc test was performed to identify which treatment pairs differed significantly. Tukey's HSD test was selected because it allows simultaneous comparison of all treatment pairs while controlling the error rate.

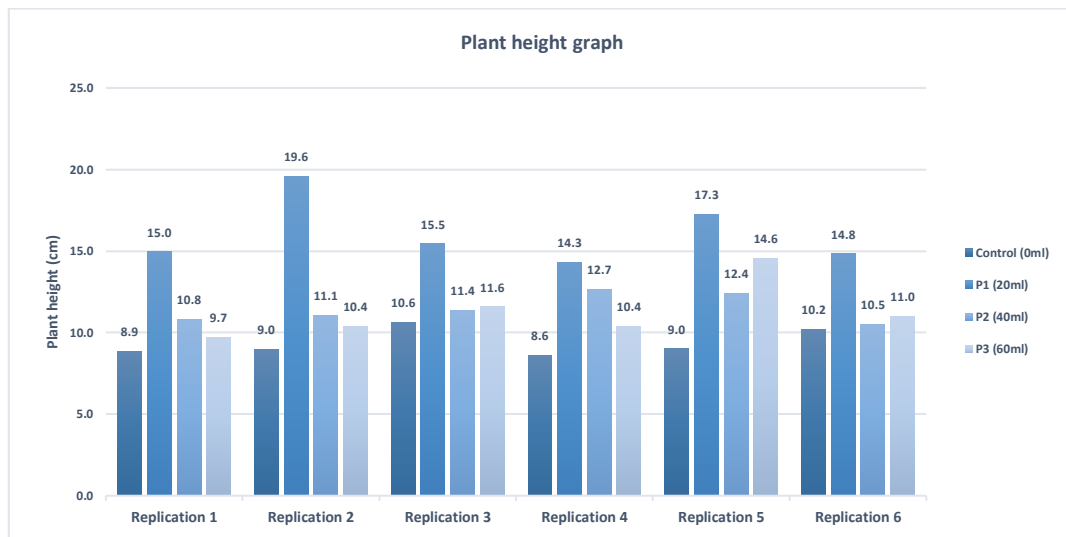
**RESULTS AND DISCUSSION**

**NPK Content of Liquid Organic Fertilizer Produced from Catfish Offal Waste and Banana Pseudostem**

Analysis of the nutrient content of liquid organic fertilizer (LOF) prepared from a mixture of catfish offal waste and banana pseudostem is necessary to determine its quality and potential use for supporting plant growth. In this study, LOF testing focused on three primary macronutrients, namely nitrogen (N), phosphorus (P), and potassium (K). Nitrogen and phosphorus contents were analyzed at the POLINELA Analytical Laboratory using the SNI 7763:2018 method, whereas potassium content was analyzed at the Integrated Laboratory and Technology Innovation Center of UNILA using EPA Method 200.7 Revision 5. Laboratory analysis showed that the liquid organic fertilizer contained several essential nutrients, including nitrogen (N) at 0.08%, phosphorus (P) at 0.09%, and potassium (K) at 15.9 mg/L.

**Effect of LOF Dose on Plant Height**

Plant height was used as a parameter to evaluate the effect of LOF application on the growth of curly chili plants. Measurements were conducted for each dosage treatment to compare plant growth responses. The results of plant height measurements are presented in the following graph.



**Figure 1.** Plant height graph of curly chili

Observations of plant height showed that fertilizer application at different doses produced different growth responses compared with the control treatment. In general, fertilized plants tended to exhibit greater increases in plant height than unfertilized plants (control).

Based on the graph, the mean plant height in the control treatment ranged only from 8.6 to 10.2 cm, whereas treatment P1 (20 mL) produced plant heights ranging from 14.3 to 19.6 cm. Treatment P2 (40 mL) showed values ranging from 10.0 to 14.6 cm, while P3 (60 mL) ranged from 9.0 to 12.7 cm. These data indicate that P1 consistently produced the greatest plant height at each observation point, reaching a peak of 19.6 cm in the second week.

The results of the descriptive statistical analysis, including the mean and standard deviation (SD) of chili plant height for each treatment, are presented in Table 1.

**Table 1.** Mean (Mean  $\pm$  SD) plant height of chili under various LOF doses

Treatment	Mean	Standard Deviation	Mean $\pm$ SD
P0	10.046	5.3418	10.046 $\pm$ 5.3418
P1	16.063	9.0254	16.063 $\pm$ 9.0254
P2	11.858	6.6783	11.858 $\pm$ 6.6783
P3	11.283	6.0075	11.283 $\pm$ 6.0075

Based on Table 1, the highest mean plant height was obtained in treatment P1, with a value of 16.063  $\pm$  9.0254, whereas the lowest mean plant height was recorded in treatment P0, at 10.046  $\pm$  5.3418. Treatments P2 and P3 showed mean plant heights of 11.858  $\pm$  6.6783 and 11.283  $\pm$  6.0075, respectively. These results indicate that LOF application at the P1 dose tended to produce better plant height growth than the other treatments, although variation within each treatment was still evident from the relatively large standard deviation values. The ANOVA results for curly chili plant height are presented in Table 2.

**Table 2.** ANOVA results for curly chili plant height

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	472,768	3	157,589	7,095	0,002
Within Groups	444,210	20	22,211		
Total	916,978	23			

The ANOVA test showed a significance value of 0.002, which was less than 0.05, indicating that LOF had a significant effect on curly chili plant height. The post hoc test results for plant height are presented in Table 3.

**Table 3.** Post hoc test results for plant height

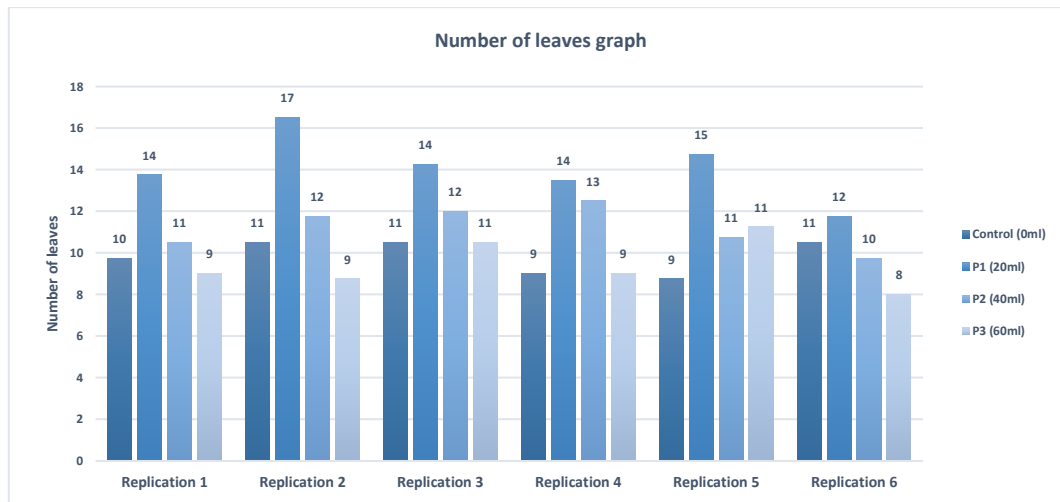
Kelompok (I)	Kelompok (J)	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
P0	P1	-11.5667*	2,7209	0,002	-19,182	-3,951
	P2	-3,9500	2,7209	0,484	-11,566	3,666
	P3	-1,5833	2,7209	0,936	-9,199	6,032
P1	P0	11.5667*	2,7209	0,002	3,951	19,182
	P2	7.6167*	2,7209	0,050	0,001	15,232
	P3	9.9833*	2,7209	0,008	2,368	17,599
P2	P0	3,9500	2,7209	0,484	-3,666	11,566
	P1	-7.6167*	2,7209	0,050	-15,232	-0,001
	P3	2,3667	2,7209	0,820	-5,249	9,982
P3	P0	1,5833	2,7209	0,936	-6,032	9,199
	P1	-9.9833*	2,7209	0,008	-17,599	-2,368
	P2	-2,3667	2,7209	0,820	-9,982	5,249

Based on Tukey's HSD post hoc test, treatment P1 showed significantly different plant height compared with P0 (Sig. = 0.002), P2 (Sig. = 0.050), and P3 (Sig. = 0.008), as the significance values were equal to or less than 0.05. This indicates that the mean value for P1 was higher than those of the other three treatments. In contrast, comparisons between P0 and P2, P0 and P3, and P2 and P3 showed no significant differences, as their significance values were greater than 0.05.

### Effect of LOF Dose on Number of Leaves

The number of leaves was used as a parameter to determine the effect of LOF application on the growth of curly chili plants. Observations were made for each dosage

treatment to compare plant responses. The results of leaf number observations are presented in the following graph.



**Figure 2.** Number of leaves graph of curly chili plants

Based on the leaf number graph, the mean value in the control treatment ranged only from 8.6 to 10.2 leaves. Treatment P1 (20 mL) produced the highest and most consistent number of leaves, ranging from 14 to 17 leaves, and was clearly higher than the control, P2 (11–12 leaves), and P3 (8–11 leaves).

The results of the descriptive statistical analysis, including the mean and standard deviation (SD) of leaf number for each treatment, are presented in Table 4.

**Table 4.** Mean (Mean ± SD) number of leaves of chili plants under various LOF Doses

Treatment	Mean	Standard Deviation	Mean ± SD
P0	9.83	4.869	9.83 ± 4.869
P1	14.08	6.94	14.08 ± 6.94
P2	11.21	5.595	11.21 ± 5.595
P3	9.42	4.624	9.42 ± 4.624

Based on Table 4, the highest mean number of leaves was obtained in treatment P1, with a value of 14.08 ± 6.94, whereas the lowest mean was found in treatment P3, at 9.42 ± 4.624. Treatment P2 showed a mean leaf number of 11.21 ± 5.595, while treatment P0 had a mean of 9.83 ± 4.869. These findings indicate that LOF application at the P1 dose tended to promote a higher number of leaves than the other treatments, although data variation within each treatment remained evident from the standard deviation values. The ANOVA results for the number of leaves of curly chili plants are presented in Table 5.

**Table 5.** ANOVA results for number of leaves of curly chili plants

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	197.833	3	65.944	8.564	0.001
Within Groups	154.000	20	7.700		
Total	351.833	23			

The ANOVA test indicated that LOF significantly affected leaf number, as the significance value was 0.001 < 0.05. The post hoc test results for leaf number are presented in Table 6.

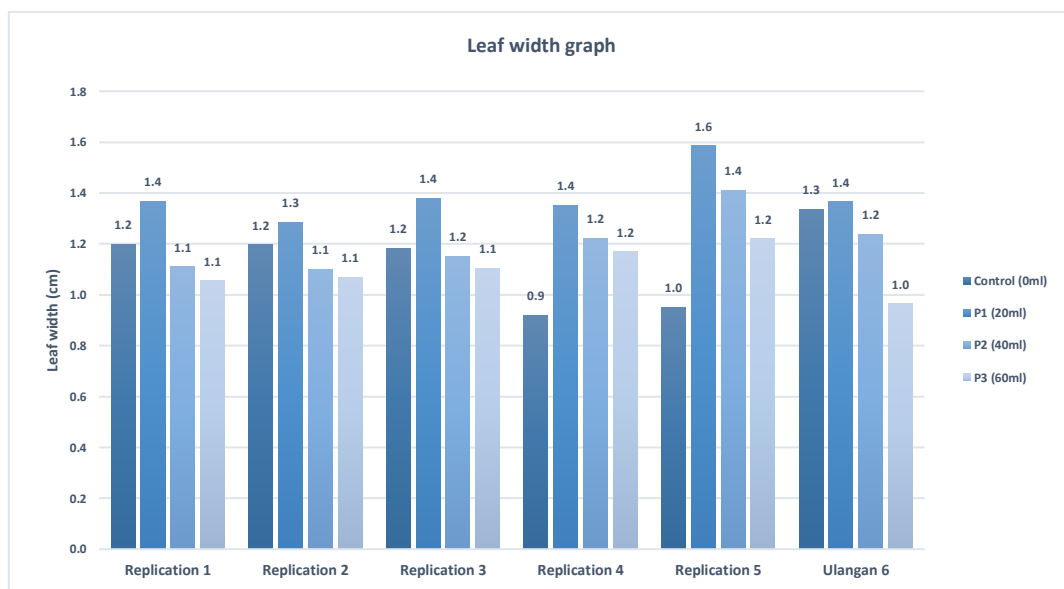
**Table 6.** Post hoc test results for number of leaves

Kelompok (I)	Kelompok (J)	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
P0	P1	-6.6667*	1.6021	0.003	-11.151	-2.183
	P2	-2.3333	1.6021	0.481	-6.817	2.151
	P3	0.6667	1.6021	0.975	-3.817	5.151
P1	P0	6.6667*	1.6021	0.003	2.183	11.151
	P2	4.3333	1.6021	0.061	-0.151	8.817
	P3	7.3333*	1.6021	0.001	2.849	11.817
P2	P0	2.3333	1.6021	0.481	-2.151	6.817
	P1	-4.3333	1.6021	0.061	-8.817	0.151
	P3	3.0000	1.6021	0.271	-1.484	7.484
P3	P0	-0.6667	1.6021	0.975	-5.151	3.817
	P1	-7.3333*	1.6021	0.001	-11.817	-2.849
	P2	-3.0000	1.6021	0.271	-7.484	1.484

Based on Tukey’s HSD post hoc test, treatment P1 showed a significant difference in leaf number compared with P0 (Sig. = 0.003) and P3 (Sig. = 0.001), as the significance values were below 0.05. This indicates that the mean value in P1 was higher than in both treatments. Meanwhile, comparisons between P1 and P2, P0 and P2, P0 and P3, and P2 and P3 showed no significant differences because their significance values exceeded 0.05.

**Effect of LOF Dose on Leaf Width**

Leaf width was used as a parameter to determine the effect of LOF application on the growth of curly chili plants. Measurements were taken for each dosage treatment. The results of leaf width measurements are presented in the following graph.



**Figure 3.** Leaf width graph of curly chili plants

Based on the graph, the mean leaf width in the control treatment ranged from 1.0 to 1.3 cm, representing the lowest values among the treatments. In contrast, treatment P1 (20 mL) produced leaf widths ranging from 1.3 to 1.6 cm, which were greater than those of the other treatments and the control. Treatment P2 (40 mL) ranged from 1.1 to 1.4 cm, whereas treatment P3 (60 mL) produced leaf widths of only 1.0 to 1.2 cm, even lower than the control. These data indicate that P1 consistently exerted the strongest effect on leaf width.

The results of the descriptive statistical analysis, including the mean and standard deviation (SD), are presented in Table 7.

**Table 7.** Mean (Mean ± SD) leaf width of chili plants under various LOF doses

Treatment	Mean	Standard Deviation	Mean ± SD
P0	1.15	0.3309	1.15 ± 0.3309
P1	1.394	0.3773	1.394 ± 0.3773
P2	1.201	0.3890	1.201 ± 0.3890
P3	1.097	0.3019	1.097 ± 0.3019

Based on Table 7, the highest mean leaf width was observed in treatment P1, with a value of 1.394 ± 0.3773, whereas the lowest mean was recorded in treatment P3, at 1.097 ± 0.3019. Treatment P2 had a mean leaf width of 1.201 ± 0.3890, while treatment P0 showed a mean of 1.15 ± 0.3309. These results indicate that LOF application in treatment P1 tended to produce greater leaf width than the other treatments, although variation among observations within each treatment was still evident from the standard deviation values. The ANOVA results for leaf width of curly chili plants are presented in the following table.

**Table 8.** ANOVA results for leaf width of chili plants

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.798	3	0.266	8.205	0.001
Within Groups	0.648	20	0.032		
Total	1.446	23			

The ANOVA results showed that LOF had a significant effect on leaf width, with a significance value of 0.001 < 0.05. The post hoc test results for leaf width are presented in Table 9.

**Table 9.** Post hoc test results for leaf width

Kelompok (I)	Kelompok (J)	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
P0	P1	-0.3167*	0.1039	0.030	-0.608	-0.026
	P2	-0.2167	0.1039	0.192	-0.508	0.074
	P3	0.1500	0.1039	0.489	-0.141	0.441
P1	P0	0.3167*	0.1039	0.030	0.026	0.608
	P2	0.1000	0.1039	0.772	-0.191	0.391
	P3	0.4667*	0.1039	0.001	0.176	0.758
P2	P0	0.2167	0.1039	0.192	-0.074	0.508
	P1	-0.1000	0.1039	0.772	-0.391	0.191
	P3	0.3667*	0.1039	0.010	0.076	0.658
P3	P0	-0.1500	0.1039	0.489	-0.441	0.141
	P1	-0.4667*	0.1039	0.001	-0.758	-0.176
	P2	-0.3667*	0.1039	0.010	-0.658	-0.076

Based on Tukey’s HSD post hoc test, treatment P1 showed significantly different leaf width compared with P0 (Sig. = 0.030) and P3 (Sig. = 0.001), as the significance values were below 0.05. In addition, P2 also differed significantly from P3 (Sig. = 0.010). In contrast, comparisons between P0 and P2, P0 and P3, and P1 and P2 showed no significant differences because their significance values were greater than 0.05.

The results demonstrated that treatment P1 (20 mL) produced the highest vegetative growth of curly chili plants, as indicated by plant height, number of leaves, and leaf width. This suggests that the dose represented the most optimal concentration

for supplying nutrients to the plants. Although the concentrations of the macronutrients nitrogen (N), phosphorus (P), and potassium (K) in the liquid organic fertilizer used in this study were relatively low compared with those in inorganic fertilizers, the observations indicate that increasing nutrient concentration does not always correspond to increased plant growth.

Nitrogen plays an important role in stimulating the growth of leaves, stems, shoots, branches, and roots, thereby enabling plants to develop a strong structure and absorb water and nutrients more efficiently (Wang et al., 2024). This element also supports tissue formation, contributing to wider leaves and stronger stems. Conversely, nitrogen deficiency inhibits plant growth, causes leaf yellowing (chlorosis), and increases plant susceptibility to damage that may ultimately lead to death (Rolanda et al., 2021). Phosphorus (P) plays a central role in ATP formation, energy transfer, cell division, and root growth. It is also important for flower development and meristematic tissue formation (Maulidan & Putra, 2024). Potassium (K) functions as a major regulator of plant physiological processes, including enzyme activation, osmoregulation, stomatal opening and closure, and translocation of photosynthates. Potassium deficiency may cause marginal chlorosis, leaf scorch symptoms, and reduced photosynthetic efficiency (Jasmi, 2016).

Physiologically, plant responses to fertilization are strongly influenced by the balance between nutrient availability in the root zone and the capacity of the root system to absorb, translocate, and assimilate nutrients (Pirhat, 2025). Nutrient uptake occurs through passive and active transport mechanisms controlled by concentration gradients and the plant's internal metabolic demands (Mailidarni & Djafar, 2025). When nutrient solution concentrations are excessively high, ion saturation, nutrient antagonism, and osmotic imbalance may occur, thereby reducing nutrient uptake efficiency and inhibiting physiological activities such as photosynthesis and cell division (Rahayu et al., 2023).

The reduced growth observed in treatment P3 (60 mL) indicates that excessively high LOF doses tend to be suboptimal for curly chili growth. Overly high LOF concentrations increase the electrical conductivity (EC) of the growing medium and inhibit water uptake (Suseno & Widyawati, 2020). In addition, unbalanced N, P, and K ratios at high concentrations may induce nutrient antagonism (Asie et al., 2025). The plant growth pattern observed in this study shows that increasing fertilizer dose was not always followed by improved growth. This is consistent with Liebig's Law of the Minimum, which states that plant growth is determined by the most limiting nutrient rather than by the total amount of nutrients supplied (Mustaqim, 2018). At the lower dose (P1), nutrient availability was relatively balanced, allowing vegetative growth to proceed optimally. In contrast, at higher doses (P2 and P3), nutrient excess led to imbalance and osmotic stress, which inhibited water absorption and reduced photosynthetic efficiency, ultimately suppressing plant growth (Rai, 2023).

The findings of this study indicate that liquid organic fertilizer (LOF) has an optimum dose for improving the growth of curly chili plants, with the 20 mL dose producing a better vegetative growth response than higher doses. This finding is in line with the study of (Putri et al., 2023), which reported that the application of LOF derived from market organic waste at certain concentrations could increase the growth and yield of curly red chili. However, that study emphasized improvement in fruit yield, whereas the present study focused only on the early vegetative phase. Another study by (Pratiwi et al., 2021) also showed that LOF application significantly affected both vegetative and generative growth of cayenne pepper, with the best results obtained at a particular concentration, indicating a similar pattern in which moderate doses

produced the most optimal results. In addition, (Mukmin et al., 2021) emphasized that liquid fertilizer produced from fish offal waste effectively enhanced plant growth and was more environmentally friendly, which is consistent with the present study in terms of using fish waste as raw material for fertilizer, although that study focused more on waste processing and ecological benefits than on testing dosage variation in relation to plant growth.

The success of this study also indicates that the utilization of catfish offal waste and banana pseudostem as raw materials for liquid organic fertilizer may serve as an economical and environmentally friendly agricultural input. Because the raw materials are derived from local organic waste, fertilizer production costs are likely to be lower than those of commercial fertilizers, which require industrial processing, packaging, and distribution. Therefore, the use of LOF from organic waste not only has the potential to improve plant growth but may also reduce fertilization costs for farmers while helping to alleviate environmental problems associated with organic waste.

Nevertheless, this study has several limitations. The observation period lasted only four weeks; therefore, the results mainly represent the early vegetative growth phase of curly chili plants. The observed parameters were also limited to vegetative indicators, namely plant height, number of leaves, and leaf width, without evaluating the generative phase. In addition, the growing medium used was relatively rich in organic matter and may already have supplied part of the basic nutrients required by the plants. This study also did not measure the pH and electrical conductivity (EC) of the growing medium; therefore, the dynamics of ionic balance in the soil solution could not be analyzed in greater depth.

## CONCLUSION

Liquid organic fertilizer (LOF) produced from catfish offal waste and banana pseudostem, containing 0.08% N, 0.09% P, and 15.9 mg/L K, significantly affected the growth of curly chili during the early vegetative phase over four weeks, as indicated by plant height, number of leaves, and leaf width. The ANOVA results demonstrated significant treatment effects, and Tukey's HSD test showed that treatment P1 (20 mL) consistently produced the highest growth. Specifically, P1 differed significantly from P0, P2, and P3 in plant height; from P0 and P3 in leaf number; and from P0 and P3 in leaf width. Practically, these findings indicate that an LOF dose of 20 mL per plant can be recommended to support the early vegetative growth of curly chili. However, this study has several limitations, including the short four-week observation period, the absence of pH and EC measurements of the growing medium, the lack of biomass and root growth evaluation, and the use of a medium containing manure that may have increased baseline nutrient availability. Future studies are therefore recommended to extend the observation period into the generative phase and to include additional parameters such as biomass, root traits, and chemical analysis of the growing medium.

## RECOMMENDATION

This study still has several limitations; therefore, further development of the fertilizer formulation and more detailed nutrient content analysis are needed. Farmers are advised to use liquid organic fertilizer as an environmentally friendly fertilizer alternative. Future studies should examine its long-term effectiveness and potential for broader-scale application.

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