Quagga
Jurnal Pendidikan dan Biologi

p-ISSN 1907-3089, e-ISSN 2615-5869
Vol 18, No. 2, 2026, pp 167 - 172
Available online https://journal.fkip.uniku.ac.id/quagga
DOI: https://doi.org/10.25134/quagga.v18i2.523

Response of Liquid Organic Fertilizer (LOF) from Tofu Wastewater and Lamtoro Leaves (*Leucaena leucocephala*) on the Growth of Red Spinach (*Amaranthus tricolor* L.)

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APA Citation: Hidayah, Pratiwi, A. & Eryati, E. (2026). Response of Liquid Organic Fertilizer (LOF) from Tofu Wastewater and Lamtoro Leaves (Leucaena leucocephala) on the Growth of Red Spinach (Amaranthus tricolor L.). *Quagga: Journal of Education and Biology*, *18(2)*, 167-172. https://doi.org/10.25134/quagga.v18i2.523.

Received: 07-04-2026 Accepted: 27-04-2026 Published: 01-07-2026

Abstract: *Tofu wastewater contains total nitrogen (N), phosphorus (P), and potassium (K) at levels of 43.37 mg/L, 114.36 mg/L, and 223 mg/L, respectively. In addition, lamtoro leaves have potential as an organic fertilizer; every 100 g of fresh lamtoro leaves yields approximately 85% dry matter, containing 20–25% protein, 20–30% free nitrogen, 5–10% fat, 3.89% energy, 1.5–2.5% tannins, 0.8–1.8% calcium, and 0.23–0.27% phosphorus. These two materials can be processed into liquid organic fertilizer (LOF) and applied to red spinach cultivated in polybags. This study aimed to analyze C-NPK content, determine the optimal concentration of LOF to enhance red spinach growth, and identify the best growth parameters influenced by LOF application derived from tofu wastewater and lamtoro leaves. The independent variable was LOF concentration with four replications and five treatments: K (0%), A (5%), B (10%), C (15%), and D (20%). The dependent variables included plant height, number of leaves, leaf width, root length, root fresh weight, root dry weight, stem fresh weight, and stem dry weight. The results showed that the LOF contained 9.64% organic C, 0.57% N, 0.042% P, and 0.358% K. The optimal concentration was treatment C (15%). The best growth parameters were observed in root length, root fresh weight, stem fresh weight, and stem dry weight.*

Keywords: *tofu wastewater, lamtoro leaves, C-NPK, liquid organic fertilizer, red spinach*

1. INTRODUCTION

Tofu wastewater contains high levels of organic and inorganic substances and produces an unpleasant odor. If not properly managed, this waste can negatively impact the environment. Tofu wastewater contains total nitrogen (N), phosphorus (P), and potassium (K) at levels of 43.37 mg/L, 114.36 mg/L, and 223 mg/L, respectively (Bakhtiar, 2022). These nutrients need to be optimized by combining them with lamtoro leaves.

Lamtoro leaves have potential as an organic fertilizer that positively affects plant growth and development (Pratiwi, 2009). According to Purwanto (2007), every 100 g of fresh lamtoro leaves yields approximately 85% dry matter, containing 20–25% protein, 20–30% free nitrogen, 5–10% fat, 3.89% energy, 1.5–2.5% tannins, 0.8–1.8% calcium, and 0.23–0.27% phosphorus.

The production of liquid organic fertilizer from these materials requires a fermentation process. Fermentation is a microbial activity, either aerobic or anaerobic, that converts chemical compounds into organic compounds. This process results in nutrient formation such as nitrogen, phosphorus, potassium, and magnesium, which are essential for plant growth (Aliyenah et al., 2015).

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One plant that requires sufficient nutrients is red spinach (*Amaranthus tricolor* L.). Optimal growth of red spinach requires macronutrients such as calcium (Ca), nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) (Mustika, 2023). Therefore, the use of LOF derived from tofu wastewater and lamtoro leaves is expected to provide an efficient nutrient source and improve red spinach production.

2. RESEARCH METHOD

Time and Location

The study was conducted from July 1 to September 23, 2023, in a greenhouse located in Pleret Market area, Yogyakarta. Red spinach seeds were obtained from Nara Kupu, Sleman, and laboratory analysis was conducted at the Biology Laboratory, Universitas Ahmad Dahlan.

Tools and Materials

The tools included hoes, soil shovels, sprayers, fermentors, blenders, polybags (25 × 25 cm), measuring cylinders, thermohygrometer, thermometer, lux meter, oven, and digital scale. Materials included red spinach seeds, tofu wastewater, lamtoro leaves, EM4, brown sugar, water, soil, and aquadest.

Experimental Design

This study used a Completely Randomized Design (CRD) with five treatments: 0%, 5%, 10%, 15%, and 20% LOF concentration, each with four replications (total 20 samples).

The dependent variables included plant height (cm), stem diameter (mm), number of leaves, leaf area (cm^2), root length (cm), root fresh weight (g), root dry weight (g), stem fresh weight (g), and stem dry weight (g).

Procedure

LOF Preparation: Fresh lamtoro leaves (2 kg) were blended with water at a ratio of 1:1 until homogenized. Subsequently, 250 mL of EM4 and 250 g of finely ground brown sugar were added and mixed thoroughly (Saragih, *et al.*, 2017). The mixture was placed in a fermentor, sealed tightly using plasticine to ensure anaerobic conditions, and fermented for four weeks.

After fermentation, the liquid was separated from the solid residue by filtration. The resulting LOF was then analyzed for C, N, P, and K content at the Soil Laboratory, Universitas Muhammadiyah Yogyakarta.

Planting: Seedlings (14 days old) were transplanted into polybags.

LOF Application: LOF was applied at a volume of 150 mL per polybag in the morning, according to the designated concentrations (0%, 5%, 10%, 15%, and 20%) for each treatment and replication.

Application began after the acclimatization period (day 21), considered as week 0 (M0), and was repeated once a week for five weeks until week 4 (M4) (Saragih, ***et al.***, 2017).

Plant Parameter Measurement

Plant parameters were measured before and after harvest. Pre-harvest measurements included plant height (using a ruler), stem diameter (using a caliper), number of leaves (using a hand counter), and leaf area (using millimeter block paper). These measurements were conducted weekly for five weeks starting from M0.

Post-harvest measurements included root length, root fresh weight, root dry weight, stem fresh weight, and stem dry weight, using a ruler and digital scale.

Measurement of Abiotic Environmental Factors

Abiotic factors measured included soil pH (using a soil tester), air temperature and humidity (using a thermohygrometer), and light intensity (using a lux meter). Measurements were conducted once a week for five weeks, starting from the first LOF application (M0).

Data Analysis

Data were analyzed using one-way ANOVA, followed by Duncan Multiple Range Test (DMRT) at 5% significance level.

3. RESULTS AND DISCUSSION

The liquid organic fertilizer (LOF) derived from tofu wastewater and lamtoro leaves was analyzed based on its physical properties and chemical composition, as presented in Table 1. The observed physical parameters included color, temperature, aroma, and pH, while the chemical components consisted of organic carbon (C-organic), nitrogen (N), phosphorus (P), and

Quagga
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potassium (K). The results showed that the final LOF had a brownish color, a temperature range of 26.1–25.4°C, an alcohol-like aroma, and an acidic pH of 4.09.

Table 1. Analysis Results of Liquid Organic Fertilizer (LOF) from Tofu Wastewater and Lamtoro Leaves

Parameter	Unit	Result	Quality Standard
Final color	-	Brownish	-
Initial temp.	^{0}C	26,1	-
Final temp.	^{0}C	25,4	-
Initial aroma		Fresh crushed leaves mixed with tofu wastewater odor	
Final aroma		Slightly alcoholic odor	
Initial pH	pH	4,09	
Final pH	pH	4,09	4-9
Nutrient Content			
C-Organic: C	%	9,64	Minimum 10%
Organic matter	%	16,62	
N Total	%	0,57	
P Total	ppm %	442,68 0,042	2-6%
K Total	ppm %	3579,985 0,58	

The fermentation process, which lasted approximately 30 days, was intended to optimize microbial degradation of the substrate. A longer fermentation period generally enhances the effectiveness of decomposition, as microbial growth and activity increase over time. This is supported by Saninta (2020), who reported that the growth and division of *Acetobacter aceti* increase significantly during fermentation. The brownish color observed in the final product is associated with microbial decomposition and the formation of dissolved organic compounds. According to Abdi (2017), brownish coloration in wastewater is caused by high organic matter content, particularly humic substances, and may be intensified by the presence of iron and dissolved organic acids.

The aroma of the LOF changed into a characteristic alcohol-like smell, indicating successful fermentation. Sundari, *et al.* (2012) stated that successful liquid organic fertilizer production can be identified by the formation of a white layer on the surface and a distinct alcohol-like odor. The relatively stable temperature during fermentation suggests that microbial activity occurred effectively, particularly in the early stages. An increase in temperature at the beginning of fermentation indicates active microbial metabolism, which supports optimal decomposition (Ediyono, 2017).

The pH value of 4.09 indicates acidic conditions, which are typical in liquid organic fertilizer fermentation. During this process, organic compounds such as carbohydrates, proteins, and lipids are decomposed by microorganisms into organic acids, resulting in lower pH values (Ulfitri, 2021). From a chemical perspective, the C-organic content met the minimum standard established by the Indonesian Ministry of Agriculture Regulation No. 70 of 2011. However, the concentrations of nitrogen and phosphorus did not meet the required standards. This deficiency may be influenced by environmental conditions, raw material composition, and microbial activity during fermentation. Marlina and Asngad (2016) reported that nitrogen levels in liquid fertilizers are affected by the type of raw materials, microbial populations, environmental conditions, and fermentation duration.

Growth of Red Spinach (Amaranthus tricolor L.)

In addition to fertilizer characteristics, abiotic environmental factors also influenced plant growth. The measured soil pH ranged from 5.2 to 7.0, which is slightly below the optimal range (pH 6–7) required for red spinach growth (Saparinto, 2013). Soil pH can be improved by adding calcium sources such as agricultural lime or nutrients from LOF. The air temperature ranged from 30.1 to 35.5°C, exceeding the optimal range of 20–32°C for red spinach, which may have limited plant growth (Saparinto, 2013). Meanwhile, air humidity ranged from 41–61%, and light intensity ranged from 4027 to 7742 lux,

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both of which also contribute to plant physiological responses.

Table 2. Measurement Results of Abiotic Parameters

Abiotic Parameter	Unit	Result
Soil pH	pH	5,2 – 7
Air temp.	°C	30,1 – 35,5
Air humidity	%	41 – 61
Light intensity	Lux	4027 – 7742

Although statistical analysis indicated no significant differences among treatments, variations in mean values revealed that the 15% LOF concentration (treatment C) consistently produced the best growth performance. This was evident in parameters such as root length (28.38 cm), root fresh weight (16.5 g), stem fresh weight (45 g), and stem dry weight (19.25 g). These results suggest that moderate nutrient concentrations provide a more balanced nutrient supply for plant growth.

For plant height, the best result was observed in treatment B (10%), which may be attributed to nitrogen availability. Nitrogen plays a crucial role in stimulating cell division in the apical meristem, thereby enhancing plant height (Triadiawarman, *et al.*, 2022). In contrast, the highest stem diameter and leaf number were observed in the control treatment (0%), suggesting that water availability and neutral pH conditions may facilitate better nutrient absorption. Wahono, *et al.*. (2018) emphasized that water plays a critical role in plant growth, particularly in cell division and elongation during the vegetative phase.

Table 3. Summary of All Growth Parameters of Red Spinach (*Amaranthus tricolor* L.)

Treatment	Plant height (cm)	stem diameter (mm)	number of leaves	leaf area (cm^2)	root length (cm)	root fresh weight (g)	root dry weight (g)	shoot fresh weight (g)	shoot dry weight (g)
K	58.88^{a}	8.48^{b}	54.75^{a}	35.37^{c}	24.00	9.25	2.25^{ab}	39.00	16.75
A	49.63^{c}	7.05^{ab}	50.00^{a}	42.06^{bc}	24.25	15.00	4.00^{b}	42.75	18.25
B	61.93^{a}	5.73^{a}	43.25^{b}	44.57^{b}	26.75	12.00	3.00^{a}	40.00	17.25
C	57.38^{b}	6.27^{a}	40.75^{bc}	54.95^{a}	28.38	16.50	3.75^{ab}	45.00	19.25
D	57.13^{b}	5.56^{a}	36.50^{c}	26.25^{d}	24.88	11.50	2.50^{a}	41.00	18.25

Notes: ANOVA and Duncan test showed significant differences ($p < 0.05$). Values followed by different letters indicate a statistically significant difference at the 95% confidence level.

Similarly, the highest number of leaves in the control treatment may be associated with optimal water absorption and its role in photosynthesis. Gardner, *et al*. (2006) explained that adequate mineral and water supply enables leaves to function efficiently as photosynthetic organs, thereby promoting vegetative growth.

On the other hand, parameters such as leaf area, root length, and biomass (fresh and dry weight of roots and stems) were optimized at the 15% LOF concentration. This is likely due to the balanced availability of essential macronutrients (N, P, and K), which are required for cell division and plant development. Gultom and Ariani (2017) stated that optimal plant growth occurs when nutrients are available in sufficient quantities and in forms that can be absorbed by plants. Nitrogen also enhances vegetative growth and chlorophyll formation (Munar, *et al.*, 2018), while adequate light intensity supports leaf expansion.

Root growth is closely related to carbohydrate distribution from photosynthesis. Increased leaf area enhances photosynthetic activity, leading to higher carbohydrate production that supports plant growth (Belit, *et al.*, 2020). Furthermore, nitrogen availability accelerates protein synthesis and cell membrane formation, contributing to biomass accumulation (Manurung, *et al.*, 2018).

Plant biomass is strongly influenced by water content, which maintains cell turgidity and supports tissue growth (Masruroh, 2008). Additionally, water availability at different growth stages is closely related to plant physiological processes and environmental conditions (Su'ud & Lestari, 2018). Stem fresh

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weight reflects the accumulation of photosynthates and water content, while stem dry weight represents the actual biomass after water removal. Purwanto, *et al*. (2015) reported that plant dry matter consists mainly of polysaccharides, lignin, proteins, lipids, amino acids, and organic acids. Furthermore, dry weight is considered an indicator of overall plant growth performance and metabolic efficiency (Sarif, 2015).

Interestingly, root dry weight showed a significant difference in treatment A (5%), suggesting that lower nutrient concentrations may enhance nutrient absorption efficiency due to better dilution. Parman (2007) stated that nutrient uptake from the environment directly affects plant development and productivity, indicating that optimal nutrient concentration is essential for efficient plant growth.

4. CONCLUSION

This study demonstrates that liquid organic fertilizer (LOF) derived from tofu wastewater and lamtoro leaves contains essential nutrients, with C-organic meeting the required standard, although nitrogen and phosphorus levels remain below optimal values. Despite suboptimal environmental conditions, the application of LOF influenced the growth performance of red spinach (*Amaranthus tricolor* L.), with the 15% concentration consistently producing the best results in key parameters, including root length, root fresh weight, stem fresh weight, and stem dry weight. These findings indicate that a moderate LOF concentration provides a more balanced nutrient supply, enhancing plant growth efficiency compared to lower or higher concentrations. Therefore, LOF from tofu wastewater and lamtoro leaves has potential as an alternative organic fertilizer, particularly when applied at an optimal concentration to maximize plant growth.

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p-ISSN 1907-3089, e-ISSN 2615-5869
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