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THE EFFECT OF LIQUID ORGANIC FERTILIZER (LOF) DERIVED FROM LEUCAENA LEAVES (*Leucaena leucocephala*) AND PINEAPPLE PEELS (*Ananas comosus* L.) ON PAK CHOI (*Brassica rapa* subsp. *chinensis*) GROWTH

PENGARUH PEMBERIAN PUPUK ORGANIK CAIR (POC) DAUN LAMTORO (Leucaena leucocephala) DAN KULIT NANAS (Ananas comosus L.) TERHADAP PERTUMBUHAN TANAMAN PAKCOY (Brassica rapa subsp. chinensis)

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ABSTRACT

Rapid population growth and increasing demand for high-quality food drive the need for innovation in the agricultural sector. The main challenge faced is how to enhance production efficiency and the quality of agricultural yields sustainably. Pak choi, one of the fast-growing crops in Indonesia, requires special attention through various innovations to support its optimal growth. One of the key factors in pak choi growth is fertilization. However, the continuous use of synthetic fertilizers can damage soil fertility. As a sustainable alternative, Liquid Organic Fertilizer (LOF) has been developed from recycled green waste, specifically Leucaena leaves and pineapple peels. This study aims to evaluate the effects of LOF application derived from these organic waste materials on pak choi growth. This research was conducted in Sugih Waras Village, Belitang Mulya District, East OKU Regency. The research method used was a Completely Randomized Design (CRD) with 5 treatments and 3 replications. Data were analyzed using ANOVA and further tested with BNJ at a 5% significance level. The results showed that the application of LOF had the best effect in the treatment was 45 ml LOF/polybag, with plant height reaching 21 cm, 23 leaves, root length of 15 cm, fresh plant weight of 116 grams, and dry plant weight of 12.1 grams.

ABSTRAK

Pertumbuhan populasi yang cepat dan meningkatnya permintaan akan pangan berkualitas tinggi mendorong perlunya inovasi di sektor pertanian. Tantangan utama yang dihadapi adalah meningkatkan efisiensi produksi dan kualitas hasil pertanian secara berkelanjutan. Pakcoy, salah satu tanaman yang tumbuh pesat di Indonesia, memerlukan perhatian khusus melalui berbagai inovasi untuk mendukung pertumbuhannya secara optimal. Salah satu faktor kunci dalam pertumbuhan pakcoy adalah pemupukan. Namun, penggunaan pupuk sintetis secara terus-menerus dapat merusak kesuburan tanah. Sebagai solusi, dikembangkan Pupuk Organik Cair (POC) yang berasal dari daur ulang limbah hijauan, seperti daun lamtoro dan kulit nanas. Adapun tujuan dari penelitan ini adalah untuk mengetahui pengaruh pemberian POC dari kombinasi limbah hijauan tersebut dan penelitian ini dilakukan di Desa Sugih Waras, Kecamatan Belitang Mulya, Kabupaten OKU Timur. Metode penelitian yang digunakan adalah Rancangan Acak Lengkap (RAL) dengan 5 perlakuan dan 3 pengulangan. Data dianalisis menggunakan uji ANAVA dan uji lanjutan BNJ dengan tingkat signifikansi 5%. Hasil penelitian menunjukkan bahwa pemberian POC memberikan pengaruh terbaik pada perlakuan 45 ml POC/polybag, dengan tinggi tanaman mencapai 21 cm, jumlah daun 23 helai, panjang akar 15 cm, bobot basah tanaman 116 gram, dan bobot kering tanaman 12,1 gram.

KATA KUNCI:
Daun lamtoro, kulit nanas, pokcoy, pupuk organik cair

1. INTRODUCTION

The rapid growth of the global population and the increasing demand for high-quality food have placed the agricultural sector under pressure to enhance production sustainably. According to data from the Food and Agriculture Organization (FAO, 2020), the global demand for food is projected to increase by 50% by 2050, necessitating innovations in agricultural systems to meet these needs. In the context of Indonesia's economy, agriculture plays a crucial role in ensuring food and nutritional security for the population while also contributing to the national economy (Badan Pusat Statistik, 2021). However, a major challenge faced by the agricultural sector is the decline in soil fertility due to excessive agricultural intensification, including the massive use of chemical fertilizers. Although chemical fertilizers can enhance productivity in the short term, they have been proven to negatively impact soil fertility, leading to a decline in soil microbial activity, the accumulation of chemical residues, and the degradation of soil structure (Simanungkalit *et al*., 2006; Chakraborty and Akhtar, 2021). Therefore, more environmentally friendly approaches are required to ensure the sustainability of agricultural systems.

One promising solution is the use of organic fertilizers, particularly Liquid Organic Fertilizer (LOF). LOF is the product of organic matter decomposition and is rich in macro- and micronutrients, which can improve the physical, chemical, and biological properties of soil (Hairiah *et al*., 2000; Adhikary, 2012). Additionally, LOF can be produced from abundant organic waste materials, such as plant residues, animal manure, and household waste, thus providing added value to waste management. In this regard, leucaena leaves (*Leucaena leucocephala*) and pineapple peel (*Ananas comosus L.*) are potential organic materials for LOF production. Leucaena leaves are known for their high nutrient content, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), which are essential for plant growth (Hairiah *et al*., 2000). Meanwhile, pineapple peel, often regarded as waste, contains carbohydrates, sugars, and organic compounds that can enrich the nutrient content of LOF (Hartono *et al*., 2012; Kumar *et al*., 2021). The utilization of these materials for LOF not only provides a solution for organic waste management but also enhances the efficient use of local resources.

Pak choi (*Brassica rapa* subsp. *chinensis*) was selected as the subject of this study due to its widespread cultivation in Indonesia. Pak choi has high economic value and is rich in essential nutrients, such as vitamins A, C, and E, which act as antioxidants and contribute to human health (Kementerian Pertanian, 2020; Liu, 2003). However, pak choi cultivation faces several challenges, including pest and disease infestations, as well as excessive reliance on chemical fertilizers. Therefore, LOF derived from leucaena leaves and pineapple peel is expected to serve as a sustainable solution for improving the growth and productivity of pak choi cultivation. Furthermore, the use of LOF can reduce farmers' dependence on chemical fertilizers, thereby promoting more environmentally friendly agricultural practices (Adhikary, 2012).

This study aims to evaluate the effects of Liquid Organic Fertilizer (LOF) derived from leucaena leaves and pineapple peel on the growth of pak choi (*Brassica rapa* subsp. *chinensis*) variety Nauli F, as well as to determine the optimal dosage of LOF application. By utilizing locally available organic materials, this research is expected to contribute to the development of environmentally friendly organic fertilizers and enhance the sustainable production of vegetable crops. Additionally, the findings of this study are anticipated to serve as a reference for farmers in adopting more sustainable agricultural practices while mitigating negative environmental impacts.

2. MATERIAL AND METHOD

This research was conducted in Sugih Waras Village, Belitang Mulya District, East OKU Regency, in 2024. The study employed a Completely Randomized Design (CRD). The treatments involved Liquid Organic Fertilizer (LOF) derived from leucaena leaves and pineapple peel, consisting of five levels: negative control without LOF application (P0), positive control using commercial organic PGR fertilizer (P1), 25 ml/L/polybag (P2), 35 ml/L/polybag (P3), and 45 ml/L/polybag (P4). Each treatment was replicated three times, resulting in a total of 15 experimental units.

The observed parameters in this study included plant height (cm), number of leaves (leaves), root length (cm), and dry weight (g). Additionally, the nutrient content of the LOF was analyzed by examining pH, macro-nutrient content (N, P, K), and micro-nutrient content (Fe, Mn, Zn). The collected data were processed using R Studio software and analyzed using Analysis of Variance (ANOVA) at a confidence level of $\alpha = 0.05$. A further Honest Significant Difference (HSD) test was conducted to determine the most effective LOF concentration for promoting pak choi growth.

The research process included seedling preparation, LOF production, transplanting pak choi seedlings, LOF application, plant maintenance, and parameter observation. The LOF was prepared by mixing 2.5 kg of leucaena leaves and 2.5 kg of pineapple peel, obtained from green waste in Sugih Waras Village, with 100 ml of EM4, 10 L of water, and 100 g of brown sugar. High-quality LOF typically exhibits a yellowish-brown color, a slightly foul odor, and a mildly acidic pH (Pramana and Hartini, 2021).

Before application, the fermented LOF was filtered using a cloth sieve to separate the liquid fertilizer from the solid residue. The LOF was then applied to pak choi plants in four application stages: the first application after transplanting, the second application at one week after transplanting (WAT), the third application at two WAT, and the fourth application at three WAT. Observations were carried out from one WAT to four WAT based on the previously mentioned parameters.

3. RESULT AND DISCUSSION

3.1 Analysis of Macro and Micro Nutrients in Liquid Organic Fertilizer (LOF)

The liquid organic fertilizer (LOF) derived from Leucaena leucocephala leaves and pineapple peels was subjected to a one-time chemical analysis at the end of the fermentation process. The results of the chemical analysis of the LOF, which was decomposed over 30 days, are presented in Table 1.

Table 1. Analysis of Macro and Micro Nutrient Content in LOF from *Leucaena leucocephala* Leaves and Pineapple Peels after 30 Days of Fermentation

No.	Test Parameter	Result	Quality Standard*
1.	Nitrogen (%)	0.28	0.5
2.	P-Total (%)	0.03	2-6
3.	Potassium (%)	0.181	2-6
4.	pH	4.7	4-9
5.	Iron (Fe) (ppm)	22.22	90-900
6.	Manganese (Mn) (ppm)	0.56	25-500
7.	Zinc (Zn) (ppm)	<0.001*	25-500

*Based on the Indonesian Minister of Agriculture Regulation No. 261/KPTS/SR.310/M/4/2019 on Minimum Technical Requirements for Organic Fertilizers, Biofertilizers, and Soil Conditioners.

The analysis conducted at the Analytical Laboratory of the Lampung State Polytechnic indicated that the LOF used in this study contained 0.28% nitrogen (N), 0.03% total phosphorus (P), and 0.181% potassium (K), with a pH of 4.7. According to the Indonesian Minister of Agriculture Regulation No. 261/KPTS/SR.310/M/4/2019, which stipulates the minimum technical requirements for organic fertilizers, biofertilizers, and soil conditioners, the macronutrient content (N, P, K) in this LOF does not meet the established quality standards. Additionally, the micronutrient content also falls below the required standard, with iron (Fe) at 22.22 ppm, manganese (Mn) at 0.56 ppm, and zinc (Zn) at <0.001 ppm, all of which are below the minimum threshold. However, the pH level of the LOF remains within the acceptable range.

Leucaena leucocephala leaves and pineapple peels were selected as raw materials for LOF due to their nutritional benefits for soil fertility and plant growth (Kusuma *et al*., 2019). Research conducted by Krisnaningsih and Suhartini (2018) reported that LOF also contains enzymes such as cellulase, ligninase, amylase, and protease, which play a role in breaking down complex organic materials into simpler compounds that plants more readily absorb.

The results of the LOF analysis indicate the presence of NPK, which is essential for plant growth. Among the macronutrients analyzed, nitrogen (N) is crucial in supporting vegetative growth, promoting leaf and stem formation, and contributing to chlorophyll synthesis, which is essential for photosynthesis. Sufficient nitrogen availability can accelerate plant growth and enhance yield (Kurniawati *et al*., 2022). Meanwhile, phosphorus (P) functions primarily in energy metabolism and supports ATP formation as the primary energy source for plants (Yosilia *et al*., 2023). Potassium (K) is essential for water regulation, helping plants control stomatal opening and closure, thereby facilitating transpiration and photosynthesis (Singh *et al*., 2014).

3.2 Plant Height

Weekly observations until the pre-harvest stage showed that treatments P2, P3, and P4 demonstrated positive results compared to the positive control (P1) and negative control (P0).

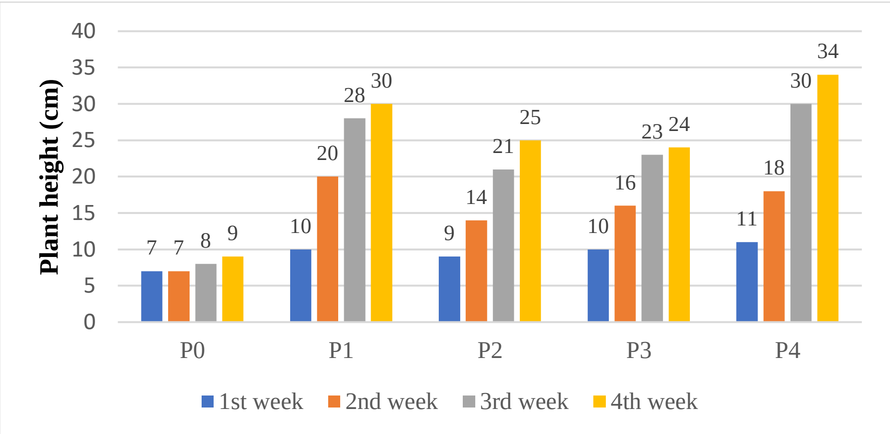

Figure 1. Average Plant Height Over 4 Weeks

Based on the graph, the application of LOF significantly increased plant growth, albeit with varying degrees of effectiveness. Treatment P1 exhibited a greater impact than P2 and P3, indicating that the ZPT Ratu Biogen fertilizer contains a higher concentration of plant growth regulators (PGRs) than the LOF derived from *Leucaena leucocephala* leaves and pineapple peels at doses of 25 mL/L and 35 mL/L. However, the effectiveness of P1 was still lower than P4, suggesting that at a dose of 45 mL/L, the LOF exhibited a superior effect compared to the ZPT Ratu Biogen fertilizer.

This increase in plant height is attributed to the high nutrient content of the LOF, which benefits plant growth. Pineapple peels contain organic acids that enhance soil nutrient availability and improve soil structure, facilitating root nutrient absorption (Sutikarini *et al*., 2023). Meanwhile, *Leucaena leucocephala* leaves are rich in nitrogen, which is vital for vegetative growth, particularly in leaf and stem development (Muchecheti and Madakadze, 2015). Nitrogen also contributes to chlorophyl synthesis, enhancing photosynthesis and plant vigor (Sharma *et al*., 2018) .

Table 2. HSD Test Results on Average Height of Pak Choi

Treatment	Average Plant Height (cm)
Without LOF	7.75^{d}
Organic PGR fertilizer	22^{ab}
LOF 25 ml/L/polybag	17.25^{c}
LOF 35 ml/L/polybag	18.25^{bc}
LOF 45 ml/L/polybag	23.25^{a}
$HSD_{0.05}$	16.64

Note: Means followed by the same letter are not significantly different.

The availability of soil nutrients, particularly nitrogen, phosphorus, and potassium, are key factors influencing plant height growth (Pedersen *et al*., 2021). An adequate nutrient supply accelerates vegetative growth, increases plant height, and optimizes yield (Pedersen *et al*., 2021). The combination of *Leucaena leucocephala* leaves and pineapple peels in LOF not only provides a more comprehensive nutrient profile but also stimulates soil microbial activity, which aids in organic matter decomposition and soil fertility enhancement. Consequently, the use of LOF from *Leucaena leucocephala* leaves and pineapple peels has been proven to significantly enhance the height of *Pak choi* plants, particularly at higher doses.

3.3 Number of Leaves

Based on the graphical results, the application of liquid organic fertilizer (LOF) demonstrated a significant increase in plant growth, although with varying effectiveness. The P1 treatment had a greater impact compared to P0, P2, and P3, indicating that the ZPT Ratu Biogen content was higher than the LOF based on Leucaena leaves and pineapple peel at a dose of 25 ml/L and a dose of 35 ml/L. However, its effectiveness was still lower than P4, which suggests that at a dose of 45 ml/L, the LOF derived from Leucaena leaves and pineapple peel began to show better effects than ZPT Ratu Biogen, particularly in increasing the number of pak choi leaves.

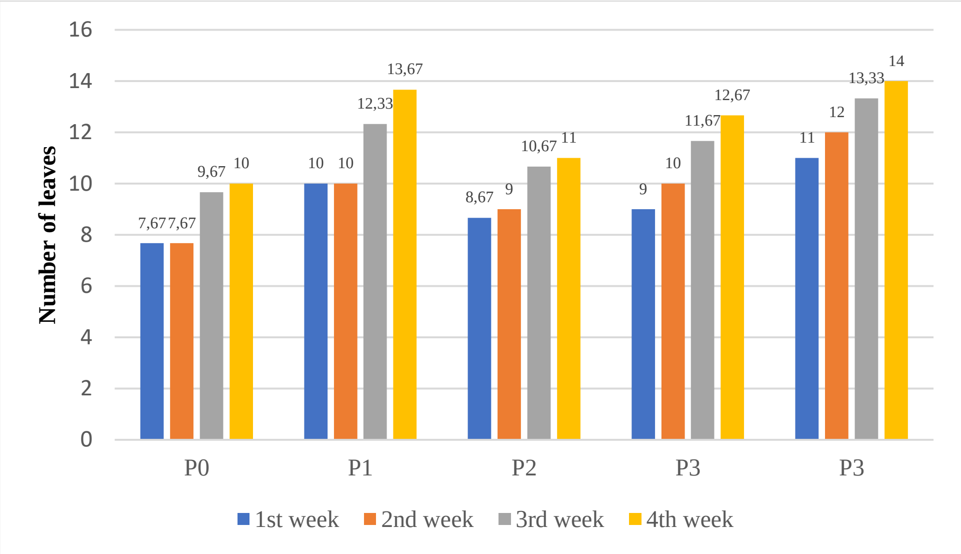

Figure 2. Graph of the average number of leaves over 4 weeks

The relationship between plant height and the number of leaves is very close, as these two factors influence each other in the growth and development process (Aditiawati *et al*., 2021). The primary components in LOF that contribute to increasing the number of pak choi leaves are nitrogen, phosphorus, and potassium. Nitrogen plays a crucial role in protein and chlorophyll synthesis, supporting photosynthesis and stimulating the formation of larger and more numerous leaves (Yosilia *et al*., 2024). Phosphorus contributes to root system development, enabling plants to absorb more nutrients and water, thus supporting optimal leaf growth (Fatima *et al*., 2024; Kim and Li, 2016). Potassium regulates water balance, enhances plant resistance to environmental stress, and strengthens leaf tissue structure.

Table 3. HSD Test Results on the Average Number of Pak Choi Leaves

Treatment	Average Number of Leaves
Without LOF	8.75[d]
Organic PGR fertilizer	11.5[ab]
LOF 25 ml/L/polybag	9.83[c]
LOF 35 ml/L/polybag	10.83[bc]
LOF 45 ml/L/polybag	12.58[a]
$HSD_{0.05}$	3.21

Note: Means followed by the same letter are not significantly different.

In addition to macronutrients, the presence of beneficial microorganisms in LOF enhances nutrient availability and improves soil structure, thereby promoting healthy root growth and increasing nutrient uptake efficiency (Singh *et al*., 2022). This combination of nutrients and microbial activity indicates that LOF based on Leucaena leaves and pineapple peel has significant potential to increase the number of pak choi leaves, ultimately contributing to overall plant productivity.

3.4 Root Length

Based on the graphical results, the application of LOF showed a significant increase in the root growth of pak choi plants, although with varying effectiveness. Interestingly, the P1 treatment exhibited a similar effect to P2. However, the effectiveness of LOF became more apparent in P3 and P4, where doses of 35 ml/L and 45 ml/L provided better results than ZPT Ratu Biogen, particularly in increasing the root length of pak choi plants.

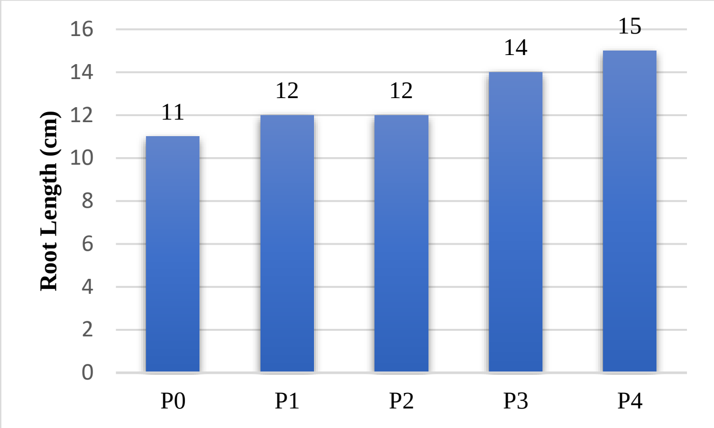

Figure 3. The average root length at harvest

The increase in root length is closely related to the availability of macronutrients, especially phosphorus, nitrogen, and potassium, which play essential roles in supporting root system development. Phosphorus is vital for forming strong and healthy roots, improving plant efficiency in absorbing water and nutrients from the soil (Fatima *et al*., 2024). Nitrogen supports root tissue growth by stimulating new cell formation (Bloom, 1997), while potassium regulates water balance and enhances plant resistance to environmental stress (Hasanuzzaman *et al*., 2018).

Table 4. HSD Test Results on Pak Choi Root Length

Treatment	Average Root Length (cm)
Without LOF	11.03[c]
Organic PGR fertilizer	12.36[bc]
LOF 25 ml/L/polybag	12.13[bc]
LOF 35 ml/L/polybag	14.26[ab]
LOF 45 ml/L/polybag	15.33[a]
$HSD_{0.05}$	1.61

Note: Means followed by the same letter are not significantly different

In addition to nutrient content, the presence of beneficial microorganisms in LOF also contributes to increased root growth (Verbon and Liberman, 2016). Microorganisms such as bacteria and fungi enhance soil biological activity, improve soil structure, and increase nutrient availability and absorption by plant roots (Hemati *et al*., 2021). Some microorganisms even form symbiotic relationships with roots, further optimizing nutrient and water uptake (Hemati *et al*., 2021). Thus, the synergy between available nutrients and microbial activity in LOF supports more optimal root system development. This not only increases the plant's ability to absorb nutrients and water but also directly contributes to the overall health and productivity of pak choi plants.

3.5 Fresh Weight of Plants

Based on the graphical results, the application of LOF significantly increased the fresh weight of pak choi plants. The P1 treatment had a greater effect than P2 and P3, indicating that ZPT Ratu Biogen was more effective than LOF based on Leucaena leaves and pineapple peel at a dose of 25 ml/L. However, ZPT Ratu Biogen was still less effective than P4, which showed that at a dose of 45 ml/L, LOF had a more positive impact than ZPT Ratu Biogen in increasing the fresh weight of pak choi plants.

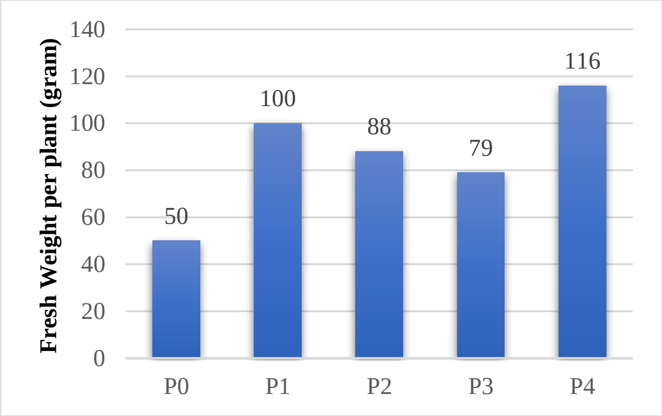

Figure 4. Graph of the average fresh weight of plants at harvest

The increase in fresh weight of pak choi plants is influenced by several key interacting factors, including water availability, nutrient balance, and biological activity in the soil. One crucial factor in plant growth is water availability, which plays a role in photosynthesis, nutrient transport, and cell turgidity. The transpiration stream facilitates nutrient transport throughout the plant (Wegner, 2014). Water status in plants and soil is measured by water potential, with positive pressure applied to leaves mimicking the negative pressure in stems (Rodríguez *et al*., 2020). Osmotic pressure significantly impacts plant growth; higher osmotic pressure in nutrient solutions can decrease fresh weight by up to 40% and alter ion ratios, disrupting metabolic balance (Conde and Azuara, 1979). Transpiration is vital for overall plant nutrition, particularly for nutrients like nitrogen, calcium, and potassium (Wegner, 2014).

The liquid organic fertilizer (LOF) used in this study contained essential nutrients and bioactive components, including organic acids and enzymes, which play a role in improving soil structure and increasing nutrient availability for plants. Beneficial microorganisms in LOF also aid in the decomposition of organic matter, enhancing biological activity in the soil and accelerating nutrient absorption by plant roots (Altomare and Tringovska, 2011).

Table 5. HSD Test Results on Pak Choi Fresh Weight

Treatment	Average Fresh Weight (g)
Without LOF	37^{c}
Organic PGR fertilizer	85^{ab}
LOF 25 ml/L/polybag	68.33^{bc}
LOF 35 ml/L/polybag	69.66^{bc}
LOF 45 ml/L/polybag	106.66^{a}
$HSD_{0.05}$	35.44

Note: Means followed by the same letter are not significantly different.

Thus, the optimal combination of water availability, nutrients, and microbial activity in LOF synergistically contributes to increasing the fresh weight of pak choi plants. This biomass increase indicates that the use of LOF based on Leucaena leaves and pineapple peel at an appropriate dosage can be a more effective alternative than ZPT Ratu Biogen liquid fertilizer in improving pak choi yield.

3.6 Dry Weight of Plants

The study results showed that the control treatment (P0) produced the lowest dry weight of pak choi plants, at 7.9 grams. Meanwhile, the application of LOF and ZPT Ratu Biogen significantly increased plant dry weight. The P1 treatment resulted in a dry weight of 10.9 grams, P2 at 10 grams, P3 at 10.8 grams, and P4 showed the highest dry weight at 12.1 grams. This increase in dry weight reflects sufficient nutrient availability in the growing medium, which plays a role in plant biomass formation.

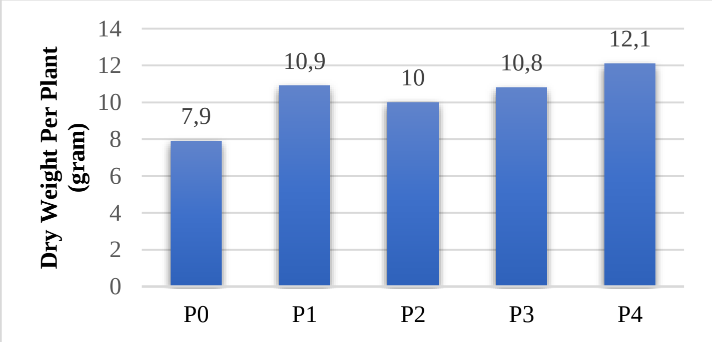

Figure 5. Graph of the average dry weight of plants at harvest

A comparison of the effectiveness of LOF and ZPT Ratu Biogen treatments showed that P1 had a greater impact than P2 and P3, indicating that ZPT Ratu Biogen was more effective than LOF based on Leucaena leaves and pineapple peel at a dose of 25 ml/L. However, the P4 treatment demonstrated that at a dose of 45 ml/L, LOF had higher effectiveness than ZPT Ratu Biogen in increasing the dry weight of pak choi plants.

The dry weight of pak choi plants is influenced by various factors related to nutrient availability, environmental conditions, and plant physiological processes. The ability of the leaves to receive and absorb sunlight will rise with leaf area, leading to a higher buildup of dry matter and photosynthetic activity (Yosilia *et al*., 2024). Drennan (1985) states that the effectiveness of each unit of leaf area in doing photosynthesis is what increases the dry weight of the plant. Greater sunlight absorption from larger leaf areas results in more photosynthate being produced and dry matter building up. Leaf area addition, as measured by specific leaf area (SLA) and leaf area partitioning, plays a crucial role in plant photosynthetic capacity and growth. SLA, defined as leaf area per unit dry mass, strongly influences photosynthetic rates and nitrogen use efficiency (Evans and Poorter, 2001; Reich *et al*., 1998). Plants with higher SLA tend to have greater mass-based photosynthetic capacity and steeper slopes in the photosynthesis-nitrogen relationship (Reich *et al*., 1998). Leaf area partitioning, which measures the allocation of photosynthate to new leaf area, is closely correlated with relative growth rates and can overshadow the effects of net assimilation rates on growth (Potter and Jones, 1977).

Table 6. HSD Test Results on Pak Choi Dry Weight

Treatment	Average Dry Weight (g)
Without LOF	7.36^{c}
Organic PGR fertilizer	10.1^{ab}
LOF 25 ml/L/polybag	8.83^{bc}
LOF 35 ml/L/polybag	9.83^{ab}
LOF 45 ml/L/polybag	11.8^{a}
$HSD_{0.05}$	2.40

Note: Means followed by the same letter are not significantly different

The role of LOF based on Leucaena leaves and pineapple peel in increasing the dry weight of pak choi plants is closely related to its content of essential nutrients and bioactive compounds. Organic acids in root exudates, especially dicarboxylic and tricarboxylic acids, can improve nutrient availability and uptake by plants (Ström and Strom, 1997). Thus, the use of LOF at an appropriate dosage plays a vital role in increasing the dry weight of pak choi plants. The study results indicate that LOF at a dose of 45 ml/L (P4) produced the best outcomes, suggesting that at this concentration, LOF can serve as a more effective organic fertilizer alternative than ZPT Ratu Biogen. The increase in the dry weight of pak choi plants is influenced by macronutrient availability (N, P, K), optimal environmental conditions, and the role of microorganisms in enhancing soil fertility.

4. CONCLUSION

Based on the research findings, it can be concluded that the application of Liquid Organic Fertilizer (LOF) has a significant impact on the growth of pak choi (Brassica rapa subsp. chinensis). LOF contributes to the improvement of all observed growth parameters, including plant height, number of leaves, root length, as well as fresh and dry weight. The optimal dosage that provides the best results in supporting pak choi growth is found in the P4 treatment with a concentration of 45 ml/L of water.

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