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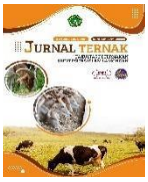

Innovative Technology for Liquid Organic Fertilizer Production from Waste in Various Elephant Grass Varieties: A Nutrient Composition Study on Ex-Oil Palm Plantation Soils

Mariam Mariam[a], A N Insani[a]*

[a] *Animal Husbandry Study Program, Muhammadiyah University of Mamuju, Jl. Pattalundru Campus 1, Mamuju, West Sulawesi*

**Corresponding Author: mariam@unimaju.ac.id*

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ABSTRACT

This study aims to evaluate the effects of liquid organic fertilizer (LOF) derived from waste materials on soil quality and the nutritional content of Napier grass grown on former oil palm plantation land. The research is motivated by the need for sustainable and environmentally friendly fertilization alternatives to improve degraded soil fertility and enhance forage quality for livestock. The methodology included chemical analysis of soil, assessment of LOF quality based on the Ministry of Agriculture standards, and evaluation of nutritional parameters in three Napier grass varieties (Bio Vit, Bio Nutrient, and Bio Grass) under four treatment levels of LOF (P0–P3). Parameters measured comprised soil and LOF pH, nitrogen (N), phosphorus (P), and potassium (K) content, as well as crude protein, crude fiber, neutral detergent fiber (NDF), and acid detergent fiber (ADF) levels in the grasses. The results indicated that the study site soil was acidic (pH 4.5) with low to very low N, P, and K levels. The applied LOF had a pH of 5 and met the required standards for N and K content but failed to meet the minimum requirement for P. Application of LOF significantly increased crude protein and reduced crude fiber, NDF, and ADF content in Napier grass, with the Bio Vit variety showing the most favorable response. Bio Nutrient exhibited stable improvement trends, while Bio Grass showed more variable outcomes, particularly in ADF levels. In conclusion, LOF application can enhance soil fertility and forage quality, particularly in marginal soils. The Bio Vit variety is recommended for its high responsiveness to LOF in improving livestock feed value.

Introduction

Sustainable agriculture has increasingly become a global concern in response to land degradation and climate change. The use of organic fertilizers or biofertilizers has demonstrated considerable potential to improve soil fertility, reduce dependence on synthetic fertilizers, and enhance the

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sustainability of food production systems (Nosheen et al., 2021). Agroecological approaches, such as regenerative agriculture, further emphasize the management of crop residues and soil microorganisms to naturally enhance nutrient cycling (Daniel et al., 2022; Mącik et al., 2020).

Former oil palm plantation lands often experience significant soil degradation, characterized by low organic matter content, increased soil compaction, and reduced soil capacity to retain water and nutrients. These conditions directly contribute to declining land productivity for agricultural and livestock purposes, particularly in the provision of forage for ruminants. To address these challenges, environmentally friendly approaches through the utilization of waste-based liquid organic fertilizers (LOF/POC) have emerged as increasingly relevant innovative solutions. Liquid organic fertilizers derived from agricultural, livestock, or household waste contain essential macro- and micronutrients that not only improve soil structure but also enhance nutrient availability for plants.

Liquid biofertilizers, including LOF or POC, contain beneficial microorganisms such as plant growth-promoting rhizobacteria (PGPR) that are capable of supplying nutrients (notably nitrogen and phosphorus) and stimulating plant growth through biological mechanisms such as phosphorus solubilization and phytohormone synthesis (Alfin et al., 2025). This approach allows for more efficient nutrient use while simultaneously improving soil structure and microbial populations (Mącik et al., 2020).

Napier grass (Pennisetum purpureum) is one of the most promising forage crops due to its rapid growth and high nutritional value, particularly in improved varieties such as Biovit, Bionutrien, and Biograss. The crude protein content, crude fiber, acid detergent fiber (ADF), and neutral detergent fiber (NDF) of this grass are strongly influenced by soil conditions and fertilization practices. Napier grass is widely recognized for its high productivity and favorable nutritional quality, making it especially suitable as livestock feed in marginal lands (Saini et al., 2025). Recent studies have shown that superior varieties can produce high biomass accompanied by optimal crude protein levels, even under dry conditions associated with global warming and moisture stress (Habte et al., 2022). Nevertheless, nutritional quality parameters such as protein and crude fiber content are highly dependent on harvest age and fertilization regimes (Meel et al., 2025).

Therefore, the application of liquid organic fertilizer across different Napier grass varieties on marginal lands, such as degraded soils of former oil palm plantations, is crucial to investigate in order to optimize the production of high-quality forage for ruminant livestock. Research by Alfin et al. (2025) reported that the use of biofertilizers increased Napier grass biomass and crude protein content by approximately 30% compared to chemical fertilizer controls. In addition, the application of liquid organic fertilizers such as biogas slurry has been shown to increase soil pH and crude protein content in Napier grass silage (Rambau et al., 2022).

This study focuses on analyzing the effects of waste-based liquid organic fertilizer application on the nutritional composition of Napier grass cultivated on degraded land. In addition to evaluating the effectiveness of liquid organic fertilizers in improving soil chemical properties such as pH, nitrogen, phosphorus, and potassium, this research aims to identify the specific responses of different Napier grass varieties to the applied treatments. The findings are expected to contribute to the development of sustainable forage production technologies and to serve as a reference for the implementation of liquid organic fertilizer technology as an integrated agricultural solution for suboptimal lands.

Method

Time and Location (Tentative)

This study was conducted from January to July 2025 in Mamuju Regency, West Sulawesi, Indonesia. The analysis of liquid organic fertilizer (LOF/POC) quality and soil chemical properties was carried out at the Soil Chemistry and Fertility Laboratory, Department of Soil Science, Faculty of Agriculture,

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Universitas Hasanuddin. Analysis of the nutritional composition of Napier grass was conducted at the Integrated Biotechnology Laboratory of Animal Science, Faculty of Animal Science, Universitas Hasanuddin.

Materials and Equipment

The materials used included rice straw, maize straw, and oil palm fronds, as well as goat urine sourced from Mamuju Regency, molasses, EM-4, and water. The equipment utilized comprised 5-L jerry cans, plastic bottles, graduated cylinders, weighing scales, and a pH meter.

Research Procedures

Preparation of Liquid Organic Fertilizer (POC)

A 20-liter container was prepared and filled with 10 liters of goat urine, 1 liter of EM-4, and 1 liter of molasses. Rice straw, maize straw, and oil palm fronds were chopped into small pieces and added to the container. All materials were thoroughly mixed, after which the container was tightly sealed and stored in a shaded area protected from direct sunlight and rain. The mixture was fermented for 21 days. Successful fermentation was indicated by a change in odor, where the initial urine smell transformed into a sour or acidic odor.

Application of POC to Plants

The POC was applied to three Napier grass varieties—Biovit, Bionutrien, and Biograss—grown in polybags filled with soil collected from former oil palm plantation land in Mamuju Regency. Each plant received liquid fertilizer at four dosage levels: control (without POC), 10, 20, and 30 mL POC per 1 liter of water.

Data Analysis

Data obtained from measurements of nutritional content and growth parameters of Napier grass were analyzed using analysis of variance (ANOVA) to determine the significance of the effects of POC dosage on the different Napier grass varieties. When significant differences were detected, post-hoc comparison tests were performed to identify the optimal POC dosage for each variety.

Results and Discussion

A. **Soil Chemical Properties**

This study aims to examine the effects of waste-based liquid organic fertilizer (LOF/POC) on soil quality and nutrient content of Napier grass grown on former oil palm plantation land. As part of the initial stage of the research, several key parameters were measured, namely soil pH, total Nitrogen (N), Phosphorus (P), and Potassium (K) in both the soil and the applied POC. The preliminary findings provide a significant initial overview of the potential role of POC in improving soil quality and enhancing agricultural productivity, particularly for forage crops used in livestock production.

Table 1. Soil Chemical Properties of the Research Site.

Chemical Property	Unit	Value	Classification*
pH	–	4.5	Acidic
Total N	%	0.10	Low
P_2O_5	ppm	10.61	Low
K	$cmol(+).kg^{-1}$	0.12	Very Low

Analysis conducted at the Soil Chemistry and Fertility Laboratory, Universitas Hasanuddin, 2025.
Classification based on the Soil Research Institute, Bogor (2009).

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1. Soil pH Measurement

1. The soil pH value obtained in this study was 4.5, which falls into the acidic category. Soil pH is a key factor determining the availability of nutrients for plant uptake. Soils with low (acidic) pH can limit the availability of several essential nutrients such as phosphorus, potassium, and magnesium, although certain plant species are able to grow relatively well under acidic conditions. According to (Insani & Mariam, 2023), excessively low soil pH can lead to increased solubility of heavy metals, which may be harmful to plant growth. Therefore, although a pH of 4.5 may still be tolerable for some crops, proper soil pH management is necessary to improve nutrient availability and achieve more optimal plant growth.

2. Nitrogen (N) Content

The total nitrogen (N-total) content of the soil was 0.10%, which is classified as low. Nitrogen is a crucial nutrient for vegetative plant growth, as it plays an essential role in protein and chlorophyll synthesis and enhances photosynthetic activity. Nitrogen-deficient soils can significantly restrict overall plant growth. Study (Mącik, M., et al., 2020) indicates that soils with low nitrogen content require additional fertilization to support plant development, particularly in lands previously used for oil palm plantations, which tend to experience nutrient depletion due to prolonged nutrient extraction. Therefore, increasing soil nitrogen levels through appropriate fertilization practices is essential to improve soil fertility in this area.

3. Phosphorus (P) Content

The phosphorus (P_2O_5) content of the soil was recorded at 10.61 ppm, which is categorized as low. Phosphorus is a vital nutrient for root development, flower formation, and fruiting. In soils with low phosphorus availability, plants may experience difficulty in developing healthy and well-established root systems. Mariam & Insani (2025), explained that phosphorus bound in unavailable forms in acidic soils can significantly limit plant growth. Consequently, in soils with low phosphorus content, phosphorus fertilization or the application of phosphorus-rich liquid organic fertilizers is necessary to support optimal plant growth.

4. Potassium (K) Content

The potassium (K) content of the soil was very low, measured at 0.12 cmol(+).kg^{-1}, and classified as very low. Potassium plays an important role in enhancing plant resistance to diseases, drought, and other environmental stresses. In addition, potassium contributes to flower and fruit development and improves overall crop quality. According to Meel.M et al., (2025), soils severely deficient in potassium tend to produce lower yields and increase the risk of plant damage due to environmental stress. Therefore, adequate potassium fertilization is required to improve plant quality and resilience under such soil conditions.

B. pH, Nitrogen (N), Phosphorus (P), and Potassium (K) Content of Liquid Organic Fertilizer (POC)

Based on the analytical results presented in Table 2, several aspects need to be discussed to gain a deeper understanding of the quality of the liquid organic fertilizer (POC).

Table 2. Chemical Properties of Liquid Organic Fertilizer (POC)

Chemical Property	Unit	Value	Standard*
pH	–	5.0	Meets
N	%	1.12	Meets
P	%	1.92	Does Not Meet
K	%	2.21	Meets

Note: Analysis conducted at the Soil Chemistry and Fertility Laboratory, Universitas Hasanuddin, 2025. Minimum POC standards are based on the Decree of the Minister of Agriculture Number

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261/KPTS/SR.310/M/4/2019 (Ministry of Agriculture, 2019).

1. pH of POC

One of the parameters evaluated in this study was the pH of the POC. The measured pH value was 5.0, indicating that the fertilizer is acidic in nature. In agricultural contexts, soil and fertilizer pH influence nutrient solubility and availability for plant uptake. A POC with a pH of 5.0 can be applied to a wide range of crops, as this value remains within a safe and acceptable range for most plants. According to Mariam & Insani (2025), excessively acidic or alkaline conditions can reduce the availability of essential nutrients such as phosphorus and potassium. The pH value meeting the regulatory standard indicates that the produced POC has good quality in terms of nutrient solubility and availability for plants.

2. Nitrogen (N) Content

The nitrogen (N) content of the produced POC was 1.12%, which meets the standard stipulated in the Decree of the Minister of Agriculture Number 261/KPTS/SR.310/M/4/2019 (Ministry of Agriculture, 2019). Nitrogen is an essential macronutrient for plant growth, particularly for leaf development and vegetative growth. Nitrogen in POC plays a role in enhancing photosynthetic activity, which directly supports plant growth. Noor, H. et al. 2023 reported that fertilizers containing adequate nitrogen can significantly improve crop yield and quality. Therefore, POC with sufficient nitrogen content is highly beneficial for improving soil fertility, especially on former oil palm plantation lands that are typically deficient in this nutrient.

3. Phosphorus (P) Content

The phosphorus (P) content of the produced POC was 1.92%. However, this value does not meet the minimum standard specified in the same regulation. Phosphorus is a crucial nutrient that supports strong root development as well as flower and fruit formation. Although the POC contains phosphorus at a moderate level, it has not yet reached the optimal concentration required to fully support plant growth, particularly in nutrient-depleted soils such as former oil palm plantation land. Cui et al. (2024) noted that liquid organic fertilizers containing adequate phosphorus levels can improve phosphorus availability in soils; however, phosphorus deficiency may limit plant growth and development.

4. Potassium (K) Content

The potassium (K) content of the produced POC was 2.21%, which meets the established standard. Potassium is an essential nutrient involved in various physiological processes, including enhancing resistance to diseases and environmental stresses, as well as improving crop quality. In this study, the potassium content of the POC met the regulatory standard, indicating its strong potential as a potassium source for plants. Zörb et al. (2014) explained that potassium plays a critical role in improving plant water-use efficiency and increasing tolerance to drought stress. Therefore, the adequate potassium content in this POC represents an added value for supporting plant growth on former oil palm plantation soils, which often suffer from declining soil fertility.

C. Nutritional Composition of Napier Grass

Table 3 presents the results of the analysis of Napier grass nutritional composition in response to the application of liquid organic fertilizer (POC) at different dosages and across varieties. The evaluation of forage nutritional quality was carried out by measuring crude protein, crude fiber, neutral detergent fiber (NDF), and acid detergent fiber (ADF), which are key indicators of digestibility, intake potential, and overall feed quality for ruminant livestock. Variations in these parameters reflect the combined effects of genetic differences among grass varieties and the effectiveness of liquid organic fertilization in enhancing nutrient uptake and plant metabolic processes. Accordingly, the data in Table 3 provide a comparative overview of the responses of three Napier grass varieties (Bio Vit, Bio Nutrient, and Bio Grass) to POC treatments on degraded land.

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Table 3. Nutritional Composition of Napier Grass

Grass Type	Parameter	Treatment			
		PO	P1	P2	P3
Napier Grass Bio Vit	Crude Protein (%)	10.60 ± 1.00[d]	11.10 ± 1.00[c]	11.50 ± 1.00[b]	12.10 ± 1.00[a]
	Crude Fiber (%)	25.00 ± 2.00[a]	23.96 ± 1.52[b]	23.50 ± 2.00[b]	22.26 ± 2.51[c]
	NDF (%)	49.90 ± 3.60[a]	48.00 ± 5.00[b]	46.00 ± 5.00[c]	44.00 ± 5.00[d]
	ADF (%)	29.90 ± 3.60[a]	28.00 ± 5.00[b]	26.00 ± 5.00[c]	24.00 ± 5.00[d]
Napier Grass Bio Nutrient	Crude Protein (%)	10.80 ± 1.00[a]	11.40 ± 1.00[a]	11.80 ± 1.00[a]	12.16 ± 1.00[a]
	Crude Fiber (%)	25.40 ± 1.00[d]	24.30 ± 2.00[c]	23.50 ± 2.00[b]	22.26 ± 2.50[a]
	NDF (%)	50.76 ± 2.51[d]	48.76 ± 2.51[c]	46.16 ± 1.04[b]	44.30 ± 2.00[a]
	ADF (%)	30.76 ± 2.51[a]	28.76 ± 2.51[a]	27.00 ± 5.04[a]	26.53 ± 3.01[a]
Napier Grass Bio Grass	Crude Protein (%)	10.60 ± 1.00[a]	11.03 ± 0.57[b]	11.50 ± 1.00[c]	12.20 ± 2.00[d]
	Crude Fiber (%)	25.16 ± 1.10[d]	24.10 ± 1.00[c]	23.50 ± 2.00[c]	22.40 ± 3.60[a]
	NDF (%)	50.23 ± 2.51[a]	50.03 ± 1.76[a]	49.60 ± 09.64[a]	47.83 ± 0.70[a]
	ADF (%)	24.33 ± 0.76[a]	30.93 ± 0.25[d]	28.90 ± 0.30[c]	27.20 ± 0.50[b]

Note: Different superscripts within the same row indicate significant differences ($P < 0.05$). Treatments: P0 = Control; P1 = Liquid fertilizer at 30 mL; P2 = Liquid fertilizer at 40 mL; P3 = Liquid fertilizer at 50 mL.

1. Napier Grass Bio Vit

Napier grass Bio Vit exhibited a highly positive response to liquid organic fertilizer (POC) application at various concentrations. An increase in crude protein content was one of the primary indicators of treatment success. The data show that crude protein increased from 10.60% under the control treatment (P0) to 12.10% under P3 (50 mL POC). This increase was statistically significant based on differences in letter notation, indicating that organic fertilizer application effectively enhanced nitrogen metabolism and protein synthesis in the plant.

In addition, crude fiber (CF) content decreased markedly from 25.00% (P0) to 22.26% (P3). This reduction is important because high crude fiber levels can limit feed digestibility. Lower CF implies a reduced indigestible fraction, thereby improving feed utilization efficiency by livestock. This trend is also associated with reduced lignocellulosic formation, which commonly occurs under stress or slow growth conditions.

Neutral Detergent Fiber (NDF) showed a declining trend from 49.90% to 44.00%. Reduced NDF indicates improved palatability and higher intake potential for ruminants. Since NDF is closely related to rumen fill capacity—higher NDF prolongs rumen retention and limits intake—the observed reduction suggests faster and greater forage consumption.

Similarly, Acid Detergent Fiber (ADF), which is associated with digestibility, decreased from 29.90% to 24.00%. Lower ADF reflects a reduced proportion of poorly digestible components such as lignin and cellulose, allowing for improved nutrient utilization. This decrease aligns with findings by Rahayu et al. (2023), who reported that organic fertilizer application reduced ADF by up to 5%.

Overall, POC application significantly improved the nutritional quality of Bio Vit grass in terms of both protein content and digestibility. These findings are consistent with previous studies (Hermansyah et al., 2024; Mariam & Nur, 2025), which reported enhanced Napier grass nutritional quality following the application of microbe-based organic fertilizers. Thus, Bio Vit appears to be a highly responsive variety to liquid organic fertilization for improving forage nutritive value.

2. Napier Grass Bio Nutrient

Napier grass Bio Nutrient also demonstrated promising improvements in forage quality following POC

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treatment. Crude protein content increased consistently from 10.80% (P0) to 12.16% (P3). Although the differences were not statistically significant (identical superscripts), the upward trend indicates a positive contribution of nutrients supplied by organic fertilizer to plant nitrogen metabolism.

Crude fiber content decreased from 25.40% to 22.26%, suggesting that POC application reduced the formation of less digestible structural tissues. This reduction approaches optimal values for high-quality forage. Purwaningsih et al. (2019) reported that organic fertilization can reduce crude fiber content by up to 3%, which is consistent with the decline observed in this variety.

NDF content decreased consistently from 50.76% to 44.30%. Lower NDF allows higher daily feed intake due to reduced rumen fill constraints. This reflects improved forage quality in terms of intake capacity and rumen turnover, ultimately supporting higher livestock productivity.

ADF content showed a more moderate decrease, from 30.76% to 26.53%. Although the reduction was less pronounced than in Bio Vit, it still indicates improved digestibility compared with the control. This supports findings by Saragih et al. (2024), who reported that POC application increased forage digestibility by 8–12%.

In summary, Bio Nutrient can be characterized as a variety with a stable response to POC, exhibiting consistent improvements in nutritional parameters without extreme fluctuations. This variety is suitable for intensive livestock systems that require balanced forage quality with optimal protein and fiber levels.

3. Napier Grass Bio Grass

Napier grass Bio Grass also responded positively to liquid organic fertilizer application, although variability was observed across certain parameters. Crude protein content increased from 10.60% to 12.20%, representing the highest value among the three varieties. Differences in superscript notation indicate that this increase was statistically significant, highlighting the strong effectiveness of POC in enhancing protein synthesis in this variety.

Crude fiber content decreased from 25.16% to 22.40%, consistent with the trends observed in other varieties. This reduction suggests suppressed development of poorly digestible structural tissues due to improved nutrient availability from POC, resulting in better feed quality and nutrient absorption efficiency.

However, NDF values in Bio Grass remained relatively high and did not differ significantly among treatments (50.23% to 47.83%). This indicates that cell wall content remained high, potentially limiting daily forage intake by livestock. High NDF is associated with longer rumen retention time, suggesting that Bio Grass may be less suitable for strategies aimed at maximizing feed intake rates.

Interestingly, ADF values in Bio Grass showed an anomalous pattern. ADF increased sharply under P1 (30.93%) and P2 (28.90%) before declining at P3 to 27.20%. This fluctuation may reflect specific interactions between POC concentration and varietal characteristics, indicating that fertilizer dosage must be carefully managed to avoid undesirable lignification.

Overall, Bio Grass performed well in terms of crude protein and crude fiber but showed greater variability in ADF and no significant response in NDF. Therefore, Bio Grass remains a viable forage option, albeit requiring more precise fertilizer management. This finding is supported by Insani and Mariam (2023), who emphasized that varietal responses to POC can differ physiologically, necessitating adaptive management approaches in cultivation.

D. Conclusions And Suggestions

Conclusion

The application of waste-based liquid organic fertilizer (POC) was proven to have a positive effect on improving soil quality and the nutritional value of Napier grass grown on former oil palm plantation land. Soils with initially acidic conditions and low nutrient availability showed improvement after POC application, particularly in nitrogen and potassium levels. The POC used in this study met quality standards for most essential nutrients, although phosphorus content remained below the required threshold. Gradual application of POC

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increased crude protein content while reducing crude fiber, NDF, and ADF levels in Napier grass. Among the tested varieties, Bio Vit exhibited the most favorable response to POC treatment, whereas Bio Grass showed greater variability in its nutritional response. Therefore, POC can be recommended as a sustainable fertilization strategy for marginal lands to support the production of high-quality forage for ruminant livestock.

Suggestions

Future studies are recommended to optimize phosphorus enrichment in liquid organic fertilizer formulations and to evaluate long-term effects of POC application on soil fertility and forage productivity under field-scale conditions, as well as to assess economic feasibility and environmental impacts to strengthen its adoption in sustainable livestock production systems.

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