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Effect of Liquid Organic Fertilizer and Inorganic Fertilizer on Soil Nutrient Content (N, P, and K) in Lowland Rice (*Oryza sativa* L.) Cultivar Ciherang

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ABSTRACT

The decline in soil nutrient availability caused by long-term inorganic fertilizer use has prompted the adoption of organic-based alternatives in paddy systems. This study aimed to evaluate the effects of liquid organic fertilizer (LOF) and its combination with inorganic NPK fertilizer on soil nutrient content—specifically total nitrogen (N), available phosphorus (P), and exchangeable potassium (K)—in lowland rice (*Oryza sativa* L. cv. Ciherang). The experiment was conducted using a randomized complete block design (RCBD) with 11 treatments: nine LOF dose variations, one recommended dose of NPK, and one unfertilized control, replicated three times. The results showed that both LOF and NPK had significant effects on soil nutrient status, with the combined application producing superior outcomes compared to single inputs. Among all treatments, the full combination of LOF and NPK (treatment H) yielded the highest nutrient concentrations: 0.30% total N, 35.65 mg/100g P_2O_5, and 36.14 mg/100g K_2O. These findings indicate that integrated fertilization enhances nutrient availability more effectively than individual applications, supporting the potential of LOF as a complementary component in sustainable nutrient management for paddy rice cultivation.

KEYWORDS: integrated fertilization, nutrient availability, paddy soil, sustainable agriculture

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1. INTRODUCTION

Rice (*Oryza sativa* L.) remains a critical staple food crop in Indonesia and many Asian countries, where its production is closely tied to soil fertility, especially the availability of macronutrients such as nitrogen (N), phosphorus (P), and potassium (K). However, long-term dependence on inorganic fertilizers has raised concerns due to associated problems such as soil acidification, nutrient leaching, and reduced microbial biodiversity (Bei et al., 2018; Qaswar et al., 2020).

Organic fertilizers, particularly in liquid form, offer a sustainable alternative to improve soil health. These materials enhance soil organic carbon, stimulate microbial activity, and gradually release nutrients in forms accessible to plants (Igalavithana et al., 2017; Samuel et al., 2018). Recent studies have reported that the use of liquid organic fertilizer (LOF) can significantly increase soil enzymatic activity, improve nutrient availability, and contribute to long-term soil productivity (Made et al., 2022).

Despite these benefits, organic fertilizers alone may not always meet the immediate nutrient requirements of modern, high-yielding rice varieties such as Ciherang. Thus, integrated nutrient management that combines organic and inorganic sources has gained attention. This approach has been shown to optimize nutrient synchronization, improve nitrogen use efficiency, stabilize yields, and enhance soil microbial diversity (Pan et al., 2021; Ma et al., 2022; Wang et al., 2023).

Given the importance of balanced nutrient supply for sustainable rice production, there is a need to evaluate the effect of liquid organic fertilizer compared to inorganic fertilizer on soil N, P, and K content, particularly in lowland rice systems. The Ciherang variety, widely adopted by farmers in Indonesia for its adaptability and yield potential, serves as a suitable cultivar for assessing these fertilization effects under field conditions.

2. MATERIALS AND METHODS

This effectiveness test was conducted on a paddy field located in Jatinangor, Sumedang Regency, West Java Province. Soil and plant nutrient analyses were carried out at the Soil Chemistry and Plant Nutrition Laboratory, Faculty of Agriculture,

Universitas Padjadjaran. The experiment was conducted from April to June 2025 using an experimental method. The design applied was a Randomized Complete Block Design (RCBD), consisting of 11 treatments: 9 treatments of various doses of liquid organic fertilizer, 1 treatment of recommended dose of inorganic fertilizer (Urea, SP-36, KCl), and 1 control treatment as a comparison. Each treatment was replicated 3 times, resulting in a total of 33 experimental plots.

Significance testing to determine the treatment effects was performed using Fisher's test at the 5% significance level. If significant differences were found, further analysis was conducted using Duncan's Multiple Range Test (DMRT) at the 5% level. The first application of liquid organic fertilizer was carried out at 14 days after transplanting (DAT), and subsequent applications using the recommended dose were repeated five times at 14-day intervals until the grain-filling stage. Inorganic Urea fertilizer was applied in three splits: one-third of the dose at transplanting, one-third at 21 DAT, and the final third at 35 DAT. SP-36 and KCl were each applied once at transplanting. Fertilizers were applied uniformly by broadcasting them on the surface of each plot between rice clumps.

3. RESULTS AND DISCUSSION

a. Effect of Treatments liquid organic fertilizer (LOF) and NPK on Soil Total Nitrogen

The effect of different combinations of liquid organic fertilizer (LOF) and inorganic NPK fertilizer on the total nitrogen content of paddy soil was evaluated. Total nitrogen is a key indicator of soil fertility and an essential nutrient for plant growth, particularly in nitrogen-demanding crops such as rice. Table 1 presents the results of total nitrogen (%) in the soil across all treatments, including control, single applications of LOF or NPK, and various integrated combinations.

Table 1. Results of Total Nitrogen

Treatments	N (%)
A = Control	0.21 a
B = 1 NPK	0.25 cd
C = ½ LOF	0.23 ab
D = ¾ LOF	0.23 bc
E = 1 LOF	0.25 bcd
F = 1 NPK + ½ LOF	0.25 bcd
G = 1 NPK + ¾ LOF	0.26 d
H = 1 NPK + 1 LOF	0.30 de
I = ¾ NPK + ½ LOF	0.25 d
J = ¾ NPK + ¾ LOF	0.26 d
K = ¾ NPK + 1 LOF	0.27 d

Note: Mean numbers followed by the same letter are not significantly different based on Duncan's Multiple Range Test at the 5% Level

The application of liquid organic fertilizer (LOF) and NPK fertilizer, either individually or in combination, significantly influenced the total nitrogen (N-total) content in the soil. The treatment combining full doses of NPK and LOF (treatment H) resulted in the highest total nitrogen content (0.30%), which was significantly greater than the control (0.21%) and even higher than treatments that received only NPK or LOF. This outcome suggests that combining organic and inorganic fertilizers can enhance nitrogen availability in the soil more effectively than applying them separately.

Previous studies have demonstrated that organic fertilizers improve soil structure, microbial activity, and the gradual release of nutrients, including nitrogen. These characteristics contribute to enhanced nitrogen retention in the soil, minimizing leaching and ensuring a more sustained supply to crops. For example, Bei et al. (2018) reported that organic fertilizers reduce nutrient loss and increase soil nitrogen retention compared to chemical fertilizers alone. Similarly, research by Qaswar et al. (2020) found that combining organic and inorganic fertilizers improves soil nitrogen content and promotes nutrient synchronization with plant demand.

Increased microbial activity facilitated by organic inputs is another contributing factor. The presence of liquid organic matter in the soil can stimulate the activity of urease and other enzymes that mineralize organic nitrogen into plant-available forms, as shown by Igalavithana et al. (2017) and Samuel et al. (2018). Such biological processes are essential for supporting plant growth in sustainable agriculture systems.

Local research conducted in West Java, Indonesia, also supports this conclusion. Nabilla et al. (2020) found that NPK fertilization combined with complementary treatments significantly increased total nitrogen in paddy soils. Likewise, Sudirja et al. (2023) reported that integrated fertilization using LOF and NPK in Inceptisol soils led to a substantial improvement in soil nutrient

status and nitrogen uptake in rice plants. These findings confirm that integrated nutrient management is more beneficial than using either fertilizer type alone, especially in rice cultivation under lowland conditions.

b. Effect of Treatments liquid organic fertilizer (LOF) and NPK on Available Phosphorus

To evaluate the effect of different fertilization strategies on soil phosphorus availability, a field experiment was conducted using various combinations of LOF and NPK on paddy rice (Oryza sativa L.) variety Ciherang. The following table presents the results of soil available phosphorus content (expressed as P_2O_5 in mg/100g) under different treatment codes, including control, single applications, and integrated applications of fertilizers.

Table 2. Results of Available Phosphorus

Treatments	P_2O_5 (mg/100g)
A = Control	19.19 a
B = 1 NPK	32.90 c
C = ½ LOF	25.54 bc
D = ¾ LOF	28.36 cde
E = 1 LOF	31.05 efg
F = 1 NPK + ½ LOF	29.93 de
G = 1 NPK + ¾ LOF	33.87 f
H = 1 NPK + 1 LOF	35.65 g
I = ¾ NPK + ½ LOF	31.19 ef
J = ¾ NPK + ¾ LOF	31.56 ef
K = ¾ NPK + 1 LOF	32.21 f

Note: Mean numbers followed by the same letter are not significantly different based on Duncan's Multiple Range Test at the 5% Level

The available phosphorus in soil is significantly influenced by the type and combination of fertilizers applied. The control treatment (A), which received no fertilization, recorded the lowest phosphorus availability, which reflects the baseline nutrient deficiency often found in unfertilized paddy fields. This condition underscores the necessity of nutrient supplementation for optimal crop performance.

The sole application of liquid organic fertilizer (LOF) at various doses (C = ½ LOF, D = ¾ LOF, and E = 1 LOF) moderately increased phosphorus levels compared to the control. Organic fertilizers enhance phosphorus availability by stimulating microbial activity and promoting the release of organic acids that mobilize bound phosphorus in the soil. However, the increases were not as substantial as those observed in treatments that included chemical fertilizer. These results align with findings by Dewi et al. (2024), who reported that LOF can improve phosphorus uptake and rice yields, especially in Inceptisols with initially low fertility.

The application of chemical fertilizer alone (B = 1 NPK) resulted in a higher phosphorus level than the control and sole LOF treatments. This is consistent with the known efficiency of mineral fertilizers in supplying soluble forms of phosphorus that are immediately available to plants. However, the sole use of NPK without organic amendments can lead to rapid fixation of phosphorus and decreased use efficiency over time, as noted in studies by Zhou et al. (2023).

Treatments combining NPK and LOF (F to K) yielded the highest increases in soil available phosphorus. In particular, treatment H (1 NPK + 1 LOF) showed the greatest improvement in P_2O_5 content, reaching 35.65 mg/100g. This suggests a synergistic effect between organic and inorganic sources, where the LOF improves microbial-mediated mineralization and phosphorus retention, while NPK provides a readily available phosphorus supply. This combined approach not only boosts short-term availability but also contributes to long-term soil fertility, as supported by long-term integrated nutrient management studies (Fan et al., 2023).

Among all the treatments, H (1 NPK + 1 LOF) was clearly the most effective in enhancing available phosphorus, followed closely by G (1 NPK + ¾ LOF) and K (¾ NPK + 1 LOF). These combinations balance the rapid nutrient release from chemical sources with the sustainable benefits of organic inputs. Therefore, treatment H can be considered the best-performing treatment for increasing phosphorus availability in this trial.

c. Effect of Treatments liquid organic fertilizer and NPK on Exchangeable Potassium Content

The Exchangeable Potassium Content (K) in soil plays a crucial role in the physiological and biochemical processes of rice plants, such as enzyme activation, water regulation, and photosynthesis. Potassium also contributes to improving grain quality and resistance to lodging and disease. The application of both organic and inorganic fertilizers can significantly influence the availability of potassium in paddy soils.

Table 3. Results of Exchangeable Potassium Content

Treatments	K_2O (mg/100g)
A = Control	22.33 a
B = 1 NPK	26.47 cd
C = ½ LOF	23.14 ab
D = ¾ LOF	25.57 c
E = 1 LOF	28.83 e
F = 1 NPK + ½ LOF	31.31 e
G = 1 NPK + ¾ LOF	34.29 f
H = 1 NPK + 1 LOF	36.14 g
I = ¾ NPK + ½ LOF	31.07 de
J = ¾ NPK + ¾ LOF	32.46 ef
K = ¾ NPK + 1 LOF	33.55 f

Note: Mean numbers followed by the same letter are not significantly different based on Duncan's Multiple Range Test at the 5% Level

Potassium is an essential macronutrient required for numerous physiological functions in rice plants, including enzyme activation, osmoregulation, and the translocation of photosynthates. Its availability in the soil is strongly influenced by fertilization strategies. The results of this study demonstrate clear differences in soil potassium levels in response to the application of both liquid organic fertilizer (LOF) and synthetic NPK fertilizer.

The control treatment (A), which received no fertilizer input, had the lowest potassium availability, highlighting the deficiency of native K in the soil and the need for nutrient supplementation to support rice production. This is consistent with findings by Arifin et al. (2021), who noted that K availability in many Indonesian paddy soils tends to be limited in the absence of fertilization.

Treatments involving the sole application of LOF at various dosages (C = ½ LOF, D = ¾ LOF, and E = 1 LOF) showed progressive increases in available K_2O compared to the control. Organic amendments such as LOF enhance soil potassium through decomposition and mineralization of organic matter, microbial activity, and improved soil structure that facilitates nutrient retention and exchange. According to Nuraini and Husnain (2022), organic inputs can increase cation exchange capacity (CEC), which plays a key role in retaining potassium in soil colloids, reducing leaching losses.

The treatment with synthetic fertilizer alone (B = 1 NPK) resulted in a moderate increase in K_2O compared to the control. Although NPK fertilizers supply readily available nutrients, potassium from these sources is susceptible to leaching, particularly in flooded or sandy soils, and may have a limited residual effect without the presence of organic matter (Yulnafatmawita et al., 2019).

The highest levels of available potassium were observed in the integrated treatments, especially those combining full doses of NPK and LOF. Treatment H (1 NPK + 1 LOF) had the greatest K_2O content (36.14 mg/100g), followed closely by treatments G (1 NPK + ¾ LOF) and K (¾ NPK + 1 LOF). This highlights the synergistic effect between organic and inorganic fertilizers. LOF enhances nutrient retention and microbial activity, while NPK ensures immediate nutrient availability. Combined applications improve the efficiency and sustainability of potassium fertilization in rice cropping systems. This interaction was also demonstrated by Prakoso et al. (2023), who reported improved soil potassium and plant uptake with integrated fertilization in wetland rice systems.

Based on these results, treatment H (1 NPK + 1 LOF) can be considered the most effective in increasing available potassium, making it the most favorable option for improving soil fertility and supporting higher rice productivity under similar soil and environmental conditions.

4. CONCLUSIONS

i. The application of liquid organic fertilizer (LOF), either alone or in combination with inorganic NPK fertilizer, significantly influenced the availability of macronutrients—namely nitrogen (N), phosphorus (P), and potassium (K)—in paddy soil cultivated with Oryza sativa L. var. Ciherang. The combined use of LOF and NPK resulted in higher nutrient availability compared to the sole application of either fertilizer type or the control treatment.

ii. Specifically, the treatment involving the full recommended dose of both NPK and LOF (treatment H) consistently produced the highest concentrations of total nitrogen (0.30%), available phosphorus (35.65 mg/100g P_2O_5), and available potassium (36.14 mg/100g K_2O). This synergistic effect indicates that integrating organic and inorganic fertilization strategies enhances nutrient retention and mobilization more effectively than single-source inputs.

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