The Availability of Soil N, P, K, and Mustard Yield After the Application of Liquid Organic Fertilizer from Household Waste in Ultisols

ABSTRACT

Ultisols are one of the dominant soil orders in Indonesia, accounting for approximately 25% of the total land area. The main problem of this soil is high aluminum (Al) saturation with low pH and plant nutrients. The study was intended to determine the effect of liquid organic fertilizer (LOF) from household waste on the availability of N, P, K, and mustard yield in Ultisols. The research used a complete randomized design (CRD) with six concentrations of liquid organic fertilizer of household waste. The treatments were repeated four times. The treatment included control, 10, 20, 30,40, and 50 ml LOF in a liter of water. The study revealed that the liquid organic fertilizer from household waste increased 1.06 folds of total soil N and 1.04 folds of exchangeable-K compared to the control but did not affect available P. Also, soil pH was comparable among treatments. The greatest concentration of LOF (50 ml per liter of water) exhibited the highest yield of mustard, indicated by the highest fresh and dry shoot weight.In general, the study contributes to the development of eco-frindly agriculture.

Keywords: Household waste Liquid organic fertilizer, Mustard, Ultisols,

1. INTRODUCTION

Ultisols are soil orders commonly used for agricultural expansion since this soil contributes aroundone-fourth of the Indonesian total land area [1]. However, this soil has limited capacity to bring about the desired plant productivity. According to [2],Ultisols contain high clay, leading to low soil permeability and poor soil porosity. Likewise, this soil has low base saturation (less than 35%), low pH, and high Al saturation [3]. The limited availability of macronutrients such as N, P, and K is also a characterizing feature of this soil[4]. A researcher [5] studied 4 Typic Hapludults and discovered that their clay minerals were dominated by kaolinitic clay with low organic carbon content, P, K, and pH ranging from 4.36-5.36.

Among 16 essential nutrients, the plant generallyrequires high amounts of N, P, and K. The function of nitrogen is to increase vegetative growth, amino acid synthesis, protein formation, and plant yield [6]. Phosphorous supports seed formation and filling, and accelerates plant flowering [7]. Meanwhile, K can increase plant resilience against pest infestation and drought [8].Thus, the improvement of N, P, and K availability in Ultisols is necessary to increase crop productivity.

Fertilization helps to increase nutrient availability in the soil to provide them for plant growth and development. Synthetic fertilizer is commonly used for delivering nutrients to plants. However, synthetic fertilizer is costly and scarce. Also, long-term and excessive use of this fertilizer leads to soil degradation. The application of synthetic N fertilizer significantly decreased soil pH over some time [9][10].The use of urea and ammonium sulfate also reduces base saturation and, at the same time, increases Al saturation [11]. [12]reported that soil microorganisms significantly decrease after applying synthetic fertilizer.

Organic fertilizer is an alternative to improve degraded soil thereby increasing the productivity of Ultosols. Waste from household activities is potential as a source of organic fertilizer. According to [13],total waste in Indonesia reached 30,783,783.82 tons in 2021, with 40.9% of household waste. High amounts of this waste can create health and environmental problems. However, it can also be a source of liquid organic fertilizer (LOF).

Liquid organic fertilizer derived from household waste has 6% organic-C and 4% N, significantly increasing mustard yield [14].Besides containing macro and micronutrients, LOF also possesses plant growth regulators such as *auxin, cytokinin* (*zeatin dan kinetin*), and dan *gibberellin*[15]. The objective of the study was to determine the effect of LOF from household waste on the availability of N, P, K, and mustard yield in Ultisols.

2. MATERIAL AND METHODS

2.1. Soil Sampling

A greenhouse experiment was conducted in Beringin Raya Village, City of Bengkulu, from November 2022 to February 2023 at approximately 15 m above sea level. Soil for the study was sampled from surrounding area ofthe greenhouse using a grid technique. A composite of 5 spots of soil sampleswere collected at a 0-20 cm depth from an area of about 1000 m^2. The soil sample was air-dried for two days, ground, and sieved using a 5 mm screen. A portion of the sample was screened using 0.5 mm for analysis of initial soil characteristics, including total soil nitrogen (TSN) using Kjeldahl method, available phosphorous(P) using Bray I method, exchangeable potassium (K) using extraction of 1N Ammonium Acetate, soil pH using pH meter at ratio of soil and distilled water at 1:1, exchangeable aluminum (Al) using 1N KCl extraction, and soil texture [16].The soil contained 0.18% TSN (low), 5 ppm available P (low), 0.23 cmol kg^{-1} exchangeable K (low), soil pH of 4.22 (very acid), 1.45 cmol kg^{-1} exchangeable Al with a textural soil classification of clay loam (27.5% sand, 38.2% silt, and 34.3% clay).

2.2. Liquid Organic Fertilizer Preparation

Liquid organic fertilizer was prepared by mixing cattle waste, topsoil, household waste, effective microorganisms, and water, as [17] suggested. The ratio of cattle waste, top soil and household waste was 1:0.5:2. The mixture was incubated in a 200 l blue plastic container for four weeks—household waste comprised of approximately 70% vegetable and 30% fruit waste. The mixture was stirred every week. After the incubation, the LOF was screened using a white cloth and ready for application. LOF was sampled to analyze carbon content, N, K, P, and pH [16]. The LOF contained 4.17% C content, 1.54% total N, 0.75% total P, 0.51% total K, and a pH of 6.25.

2.3. Experimental Design and Media Preparation

The experiment employed a completely randomized design (CRD) with six treatments and four replicates. The treatments included control, 10, 20, 30, 40, and 50 ml LOF/ L water. Two weeks before planting, dolomite was mixed with the soil at a rate of 4.2 tons ha^{-1}, equivalent to 10 g $polybag^{-1}$. Five kg of soil sample was homogeneously incorporated with 52 g vermicompost in a polybag four days before planting. Polybags were randomly placed on wooden racks in the greenhouse.

2.4. Experimental Procedure

The study used mustard (*Brassica juncea L.*) var Kumala. The mustard seedling was placed in a tray with a medium of soil and sand mixture at 1:1. Seedling was ready for transplanting when the plant had two leaves (7 days after seedling). Mustard seedlings were transplanted in the morning with one seedling per polybag. LOF was applied every week for four weeks by decanting 100 ml per polybag.

During the mustard growth period, the pest was controlled using Phefoc for insects and Nofatek for fungi and bacteria. The pesticide was homogeneously sprayed into the whole plant. Phefoc was applied every week, while Nofatek was applied every ten days. Weed was controlled manually, when necessary, by pulling out the plant. Mustard was harvested 30 days after replanting, indicated by most bottom leaves turning yellow and other leaves looking freshly green. After harvesting, a soil sample was collected, then air-dried for two days, ground, and analyzed for total-N using the Kejdahl method, available P using the Bray I method, and exchangeable K using extraction with 1N Ammonium Acetate and detecting using flame-photometer.

2.5. Data Analysis

Data was analyzed using ANOVA at a confidence level of 95%, and treatment means were compared using LSD at a confidence level of 5%.

3. RESULTS AND DISCUSSION

3.1. Effect of LOF on N, P, and K of the Soil

Liquid organic fertilizer from household waste significantly influenced total soil nitrogen (TSN) and exchangeable K, but it did not affect available P and soil pH.Total soil nitrogen increased prominently after applying 10 ml l^{-1} LOF, even though it did not differ from higher concentrations up to 50 ml l^{-1} (Figure 1). Soil N increases by more than 82% with the application of the lowest concentration of LOF (Figure 1a). The increase in N is highly associated with the release of N from the decomposition of household waste [18] as indicated by N content in LOF (1.5% N). A study by [19]found a similar result where applying Tithonia-based LOF linearly increased the total soil nitrogen of Inceptisols in tropical highlands. A study by [20] also confirmed that LOF enhanced N content in sandy soil.

Potassium in soil was also the highest in treatment at 50 ml l^{-1} LOF, but it did not differ from 40 ml l^{-1}. Applying LOF at a rate of 20 ml l^{-1} was sufficient to increase exchangeable K in Ultisols, even though it was not different from 30 and 40 ml l^{-1} (Figure 1c). The increase in exchangeable K reaches more than twofold in the highest application than control. This result is highly related to the contribution of K from LOF, which contains 0.5% of K. Higher application of LOF consequently increases exchangeable K of the soil. A study by [21] confirmed that LOF from banana stems and coconut husks increased K content in Alfisols. Another result also shows that LOF from animal waste-based LOF enlarged the K content in Ultisols[22]. Different patterns to N and K in soil, the application of LOF from household waste did not affect available P (Figure 1b). Applying the LOF up to a rate of 50 ml l^{-1} was insufficient to increase the available P in Ultisols. This might be due to the high concentration of Al in the soil. The soil used in this study has an exchangeable Al of 1.45 cmo kg^{-1}. High concentrations of the element and phosphate in soil solution might have precipitated into insoluble aluminum phosphate [23][24][25].A similar result was reported by [26] where the treatment of LOF did not affect soil-available P.

Like P, soil pH was not significantly different among LOF doses used in the experiment, even though there is a trend of increasing pH after the treatment of 30 ml l^{-1} (Figure 1d). When the amount of humic and fulvic acids in LOF is sufficient, the pH of the soil will increase. The humic and fulvic acids might be responsible for the rise in pH of acid soil by the formation of insoluble Al-organic complex [27.The formation decreases Al hydrolysis in soil solution and raises the pH [28]. Previous studies revealed different results, where applying LOF from various sources significantly increased the soil pH [19][29][30]. However, [26] found a similar result with an increase in soil pH as affected by the application of LOF. The different effects of LOF on soil pH might be associated with the differences in its sources and dose.

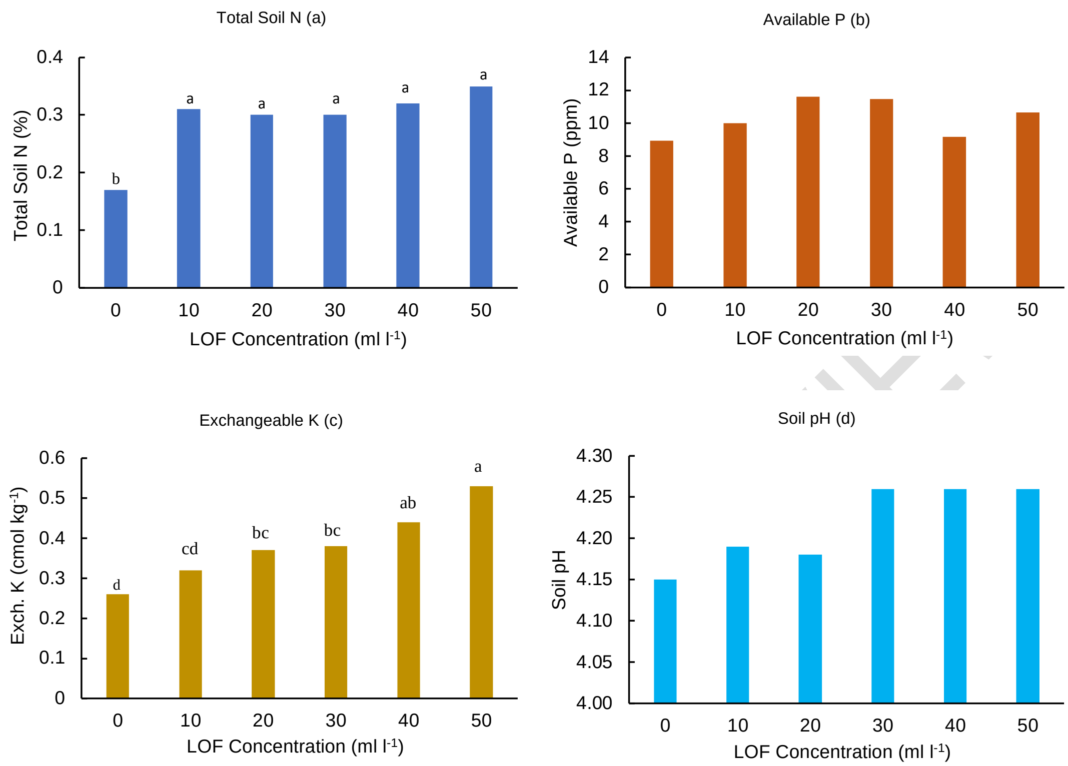

Figure 1. Effect of liquid organic fertilizer from household waste on N, P, and K of the soil

3.2. Effect of LOF on the Growth and Yield of Mustard

The improvement of soil N and K significantly impacts the growth of mustard, as indicated in Table 1. Liquid organic fertilizerfrom household wastes at a rate of 50 ml l^{-1} increases plant height by 77% compared to control. Applying LOF up to 40 ml l^{-1} did not affect this variable, indicating that mustard plant height will increase when soil is fertilized with more than 40 ml l^{-1}. The tallest mustard was achieved in treatment with the greatest rate, which is taller than the height potential of mustard var Kumala as described in [31] (32-33.3 cm).

The number of leaves follows taller mustard. Table 1 indicates that the greatest concentration of LOF exhibited the most significant number of mustard leaves, even though it is not different from 30- and 40-ml l^{-1}. The increase in mustard leaves reaches approximately 19% higher than control. This number is also higher than its potential of mustard var. Kumala, which is consumable mustard, leaves 9-10 pieces.

Mustard is commonly consumed in fresh shoots. The study showed that shoot fresh weight is the highest in treating 50 ml l^{-1} (Table 1). The increase in the yield of mustard in the greatest concentration is 83.7% higher than that of control. The application of LOF from household waste up to 40 ml l^{-1} was insufficient to increase the yield of mustard in Ultisols. A similar trend was observed in shoot dry weight, where the highest is achieved at the rate of 50 ml l^{-1}.

The increase in the growth and yield of mustard is highly associated with improving soil fertility, mainly higher soil N and K. Nitrogen has a role in photosynthesis in leaves. At the same time, P is an essential component in adenosine diphosphate (ADP) and adenosine triphosphate (ATP), which influences the development of plant organs [32].Higher N availability in the soil as an increase in LOF rates consequently increases the growth of mustard, as indicated in Table 1. Previous studies exhibited similar results where fertilization using LOF significantly increased plant height, number of leaves, N uptake, and shoot weight of mustard [33][20][34][35][36].

Table 1. The effect of LOF from household waste on mustard growth

LOF Concentration (ml/L)	Plant Height cm)	Number of leaves	Shoot fresh weight (g)	Shoot dry weight (g)
0	24.75 b	18.75 b	95.25 b	5.25 b
10	26.50 b	19.25 b	117.75 b	7.25 b
20	26.13 b	19,75 b	117.00 b	7.00 b
30	27.98 b	21.50 a	122.25 b	7.50 b
40	28.68 b	22.25 a	126.00 b	7.75 b
50	43.75 a	22.25 a	175.00 a	12.5 a
LSD	*	*	*	*

Note: * = significant at 5%. The number in a column with the same letter is not significantly different.

4. CONCLUSION

Liquid organic fertilizer from household waste at a rate of 50 ml l^{-1} increased 106% of total soil N and 104% of exchangeable K in Ultisols. However, the availability of P and soil pH were not significantly different among rates of LOF. The highest yield of mustard was achieved by applying LOF at the rate of 50 ml l^{-1}, indicated by the fresh and dry shoot weights (175 and 12.5 g $plant^{-1}$, respectively). This study's finding is essential for managing mustard cultivation in sustainable agriculture.

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