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APPLICATION OF MAGGOT FERTILIZER AND ROCK PHOSPHATE ON NPK CONTENT OF GOLD MINE SOIL

APLIKASI PUPUK MAGGOT DAN BATUAN FOSFAT ALAM TERHADAP KANDUNGAN NPK TANAH PASCA PENAMBANGAN EMAS

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ABSTRACT

Post-gold mining soils are generally characterized by acidic pH, low organic carbon (C-organic) content, and poor macronutrient levels, particularly nitrogen (N), phosphorus (P), and potassium (K). This study aimed to evaluate the effect of applying organic fertilizer derived from maggot livestock waste and natural phosphate rock on soil pH, C-organic, and N, P, and K content in post-gold mining land. The research employed a factorial completely randomized design (CRD). The first factor was maggot-based organic fertilizer applied at three rates: 0 g/pot, 8.3 g/pot, and 16.6 g/pot. The second factor was natural phosphate rock, also at three rates: 0 g/pot, 0.16 g/pot, and 0.33 g/pot. This resulted in 9 treatment combinations, each replicated 3 times, for a total of 27 experimental units. Soil parameters analyzed included pH, C-organic, total N, available P, and available K. Data were analyzed using analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) at the 5% significance level where applicable. The results indicated that maggot fertilizer significantly increased the availability of P and K, while natural phosphate rock significantly increased available P. A significant interaction between maggot fertilizer and phosphate rock was observed for soil pH. The optimal combination for improving pH was the application of 20 tons/ha of maggot fertilizer (equivalent to 16.6 g/pot) and 400 kg/ha of natural phosphate rock (equivalent to 0.33 g/pot).

Keywords: maggot fertilizer, natural phosphate rock, post-mining soil, soil nutrients, organic matter

ABSTRAK

Lahan pasca penambangan emas umumnya memiliki tanah dengan pH yang masam, kandungan C-organik yang rendah, serta miskin unsur hara makro seperti N, P, dan K. Penelitian ini bertujuan untuk mengetahui pengaruh pemberian pupuk organik limbah ternak maggot dan batuan fosfat alam terhadap pH, C-Organik, serta kandungan N, P, dan K pada tanah pasca penambangan emas. Metode penelitian menggunakan Rancangan Acak Lengkap Faktorial (RALF). Faktor pertama yaitu pupuk organik limbah ternak maggot dengan 3 dosis yaitu 0 gr/pot, 8.3 gr/pot, dan 16.6 gr/pot, sedangkan faktor kedua yaitu batuan fosfat alam dengan 3 dosis yaitu 0 gr/pot, 0.16 gr/pot, dan 0.33 gr/pot, sehingga terdapat 9 kombinasi dengan pengulangan sebanyak 3 kali sehingga didapatkan

27 perlakuan. Parameter analisis yaitu pH, C-Organik, N-total, P-tersedia, dan K-tersedia. Untuk mengetahui pengaruh perlakuan data pengamatan dianalisis dengan sidik ragam (ANOVA) dan dilanjutkan menggunakan *Duncan Multiple Range Test* (DMRT) pada taraf 5% apabila hasil berbeda nyata. Hasil penelitian menunjukkan bahwa aplikasi pupuk maggot berpengaruh terhadap kenaikan P-tersedia dan K-tersedia, sedangkan batuan fosfat alam berpengaruh terhadap kenaikan P-tersedia. Kombinasi aplikasi pupuk organik limbah ternak maggot dan batuan fosfat alam menunjukkan interaksi pada parameter pH. Kombinasi perlakuan terbaik untuk meningkatkan pH yaitu pupuk maggot 20 ton/ha atau setara 16.6 gr/pot dan batuan fosfat alam 400 kg/ha atau setara 0.33 gr/pot.

Kata kunci: pupuk maggot, batuan fosfat alam, lahan pasca penambangan, hara tanah, bahan organik

INTRODUCTION

Post-mining land management requires serious attention due to its potential to cause severe environmental degradation if not properly rehabilitated. In Indonesia, particularly in regions such as Kalimantan, illegal gold mining, commonly referred to as PETI (*Pertambangan Tanpa Izin*), has become a significant concern. One of the most environmentally harmful practices associated with illegal gold mining is the amalgamation process using mercury (Hg), which not only contaminates the environment but also degrades soil quality. The residual effects of such activities include increased soil acidity and a marked decline in soil health and fertility.

Post-mining land typically exhibits poor physical and chemical properties, including low water retention capacity, minimal organic matter content, and extremely low levels of essential nutrients. For example, research by Manullang et al. (2021) reported that soil from former illegal gold mining sites exhibited a pH of 3.84 (strongly acidic), C-organic content of 1.03% (low), total nitrogen (N) content of 0.05% (very low), available phosphorus (P) of 0.43 ppm (very low), and exchangeable potassium (K) of 0.60 cmol/kg (high). In addition, mercury concentrations reached 0.38 mg/kg, approaching critical threshold limits for environmental and health safety. These conditions reflect a highly degraded soil system that is unsuitable for plant growth and poses significant environmental risks.

The specific site of this study is a post-gold mining area in Kalimantan characterized by Red-yellow Podzolic soil, which is classified as acidic soil. This soil type is prevalent in many tropical regions and is typically characterized by low fertility, particularly low levels of essential macronutrients such as nitrogen (N), phosphorus (P), and potassium (K). The acidity of such soils also contributes to the high solubility of aluminum (Al) and iron (Fe), which bind with phosphorus to form insoluble compounds such as Al-P and Fe-P, thereby rendering phosphorus unavailable to plants. This presents a major limitation for soil productivity and crop cultivation.

To address the issue of low phosphorus availability in acidic soils, one approach is the application of natural phosphate rock. Unlike synthetic fertilizers, natural phosphate rock releases phosphorus slowly, making it particularly suitable for acidic soils with high P fixation potential. The slow-release nature of phosphate rock helps maintain phosphorus availability over time and supports sustainable soil fertility improvement.

However, the efficiency of phosphate rock in supplying phosphorus can be limited under certain soil conditions. To enhance its effectiveness, it can be combined with organic amendments. Organic materials can improve soil structure, increase microbial activity, and facilitate the release of bound nutrients. In particular, organic acids produced during the decomposition of organic matter can help dissolve phosphate compounds bound to Al and Fe, converting them into forms available to plants. According to (Tian *et al*., 2021), organic acids provide protons and form complexes with metal ions, which enhances the solubility of Ca-P, Al-P, and Fe-P compounds.

An emerging source of organic fertilizer that holds significant promise is maggot fertilizer, a byproduct of *Black Soldier Fly* (BSF) larvae rearing. Commonly known as maggot fertilizer, this organic amendment is produced from the residue of organic waste processed by BSF larvae. Maggot fertilizer is rich in nutrients and organic matter. According to Nirmala et al. (2020), maggot fertilizer contains 2.29–3.27% nitrogen (very high), 1.15–3.37% phosphorus (low), 5.09–9.74% potassium (very high), and 39.08–47.46% C-organic (very high). In addition to supplying nutrients, it contributes organic acids that can mobilize phosphorus in acidic soils.

The use of maggot fertilizer in combination with natural phosphate rock has the potential to rehabilitate degraded post-mining soils. The organic matter in maggot fertilizer improves soil structure and microbial activity, while the organic acids it releases help unlock phosphorus from insoluble compounds. At the same time, the phosphate rock supplies a steady source of phosphorus, enhancing the soil's nutrient profile over time. The synergy between these two amendments may improve soil pH, increase C-organic levels, and enhance the availability of essential macronutrients, particularly N, P, and K.

Given the potential of this integrated approach, this study was conducted to investigate the interaction effects of maggot fertilizer and natural phosphate rock on the chemical properties of Red-yellow Podzolic soil in a post-gold mining area. Specifically, the research aims to assess changes in soil pH, organic carbon, and macronutrient (N, P, K) availability resulting from the application of these soil amendments. The findings are expected to contribute to the development of sustainable strategies for post-mining land rehabilitation, especially in regions affected by illegal gold mining activities.

MATERIALS AND METHODS

Study Site

The study was conducted from April to August 2023 in the greenhouse of the Faculty of Agriculture, Universitas Pembangunan Nasional “Veteran” Yogyakarta. Soil samples were collected from a post-gold mining area in Sanggau, West Kalimantan, which is characterized by Red-yellow Podzolic soil with strongly acidic properties. Soil analysis was performed at the Laboratory of the Assessment Institute for Agricultural Technology (AIAT) Yogyakarta and the Soil and Agroclimate Research Institute (Balingtan) in Pati, Central Java.

Experimental Design

This study employed a factorial completely randomized design (CRD) with two treatment factors, each consisting of three levels. The first factor was the application of organic fertilizer derived from maggot livestock waste (Black Soldier Fly residue), which included three levels: no fertilizer (M0), 10 tons per hectare (M1), and 20 tons per hectare (M2). These rates were converted to pot-scale equivalents of 0 g, 8.3 g, and 16.6 g per pot, respectively. The second factor was the application of natural phosphate rock, also applied at three levels: no phosphate rock (P0), 200 kilograms per hectare (P1), and 400 kilograms per hectare (P2), which correspond to 0 g, 0.16 g, and 0.33 g per pot, respectively. The combination of these two factors resulted in nine treatment combinations, each replicated three times, resulting in a total of 27 experimental units. The size of the polybag pot when folded: 15 x 10 cm (length x width) with a distance between pots of 25 cm. This design allowed for the evaluation of both individual and interactive effects of organic fertilizer and phosphate rock on soil chemical properties in a controlled greenhouse environment.

Soil Preparation and Pot Experiment

The air-dried soil samples were sieved and homogenized before being weighed and placed into pots. Each pot contained 2.14 kg of air-dried soil, equivalent to 2 kg of oven-dry (absolute) weight. Fertilizer treatments were applied uniformly to the soil surface and mixed thoroughly before planting. During the experimental period, the pots were maintained under greenhouse conditions with controlled watering and no additional fertilizer inputs.

Parameters Observed

The parameters observed in this study focused on the chemical properties of the soil following treatment applications. These included soil pH, organic carbon (C-organic), total nitrogen (N-total), available phosphorus (P-available), and exchangeable potassium (K-available). Soil pH was measured using a pH meter in a 1:2.5 soil-to-water suspension. The C-organic content was determined using the Walkley-Black method, while N-total was analyzed using the Kjeldahl method. P-available was measured using Bray I extraction, and K-available was assessed through ammonium acetate extraction at pH 7.

Data Analysis

The collected data were subjected to Analysis of Variance (ANOVA) to assess the main and interaction effects of the treatments on the observed soil parameters. When significant differences were found at the 5% level, the means were further compared using Duncan's Multiple Range Test (DMRT). All statistical analyses were conducted using standard statistical software using the SAS OnDemand for Academics website.

RESULTS AND DISCUSSION

Initial Soil Analysis

The results of the initial analysis of Red-yellow Podzolic soil prior to treatment indicated limitations in soil chemical fertility, with minimal levels of essential nutrients, as presented in Table 1.

Table 1. Initial characteristics of Red-yellow Podzolic soil before treatment

Parameter	Value	Unit	Category
pH H_2O	3.90		Very acidic
C-Organic	0.04	%	Very low
N-Total	0.27	%	Moderate
Available P	0.62	ppm	Very low
Available K	7.58	ppm	Very low

The very acidic pH of the soil may result from several factors, including the parent material, high rainfall leading to leaching, low organic matter content, and ongoing base cation loss. Due to the acidic nature of Podzolic soil, aluminum (Al) and iron (Fe) ions dominate the soil colloids. These elements bind with phosphorus (P), forming insoluble compounds such as Al-P and Fe-P, thus limiting the availability of P to plants. Furthermore, the extremely low organic matter content in Podzolic soils exacerbates phosphorus deficiency, as organic matter plays a key role in the mineralization and release of bound phosphorus. that soil organic matter significantly influences phosphorus availability, as it contributes to the solubilization of P through the production of organic acids and chelating agents. Therefore, both low soil pH and limited organic matter content act synergistically to reduce the availability of macronutrients, particularly phosphorus, in Podzolic soils.

Analysis of Maggot Fertilizer and Natural Phosphate Rock

The results of the analysis of maggot organic fertilizer (Table 2) indicate that it meets the minimum technical standards for organic fertilizers as outlined in the Decree of the Minister of Agriculture No. 261/KPTS/SR.310/M/4/2019. This is evidenced by its C/N ratio, which falls within the recommended range of 10–20%, signifying balanced decomposition and suitability for soil application. The organic carbon (C-organic) content is relatively high and satisfies the standard for organic fertilizers, as do the pH and total nitrogen (N) values. However, the contents of P_2O_5 and K_2O fall below the required thresholds and thus do not meet the criteria for solid organic fertilizers as specified in the regulation.

The analysis of the natural phosphate rock sample (Table 2) shows a neutral pH (6.92) and a P_2O_5 content of 9.84%. Although the pH is favorable for soil application, the P_2O_5 content does not meet the minimum standard set by the Indonesian National Standard. which requires a minimum phosphate content of 10% for phosphate rock fertilizers.

Table 2. Characteristics of maggot fertilizer and natural phosphate rock

Sample	Parameter	Unit	Value	SNI*
Maggot fertilizer	pH H_2O		6.89	4 - 9
	C-Organic	%	51.59	Min. 15
	N	%	2.88	(N+P+K) Min 2
	P_2O_5	%	0.91	
	K_2O	%	1.20	
Natural phosphate rock	pH H_2O		6.92	4 – 9
	P_2O_5	%	9.84	(N+P+K) Min 2

SNI *: the Minister of Agriculture No. 261/KPTS/SR.310/M/4/2019

Soil Analysis After Treatment

A. Soil pH H_2O

Soil reaction is expressed by the pH value (potential of hydrogen), which reflects the concentration of H^+ ions in the soil solution. A neutral pH condition facilitates nutrient solubility in water and plays a crucial role in the activity and population of soil microorganisms. Beneficial soil microbes such as bacteria and fungi tend to thrive at pH levels above 5.5, whereas their growth is inhibited in more acidic conditions (Hardjowigeno, 2015). In this study, the application of maggot fertilizer and natural phosphate rock significantly influenced soil pH. The results of the analysis of variance (ANOVA) for the pH H_2O parameter showed a significant interaction between the two treatment factorsin increasing the pH of Red-yellow Podzolic soil (Table 3).

Table 3. Effect of maggot fertilizer and natural phosphate rock on soil pH H_2O

Maggot Fertilizer	Natural Phosphate Rock			Means
	P0	P1	P2	
M0	3.90 a	4.16 ab	4.32 bc	4.13
M1	4.13 ab	4.44 bc	4.63 cd	4.40
M2	4.83 de	4.52 cd	5.13 e	4.83
Means	4.29	4.37	4.69	(+)

Note: The (+) sign indicates that there is interaction between treatments.

The pH value increased progressively with the application of higher doses of both maggot fertilizer and natural phosphate rock. This trend is illustrated in Figures 1 and 2, which show the pH changes across the different treatment levels.

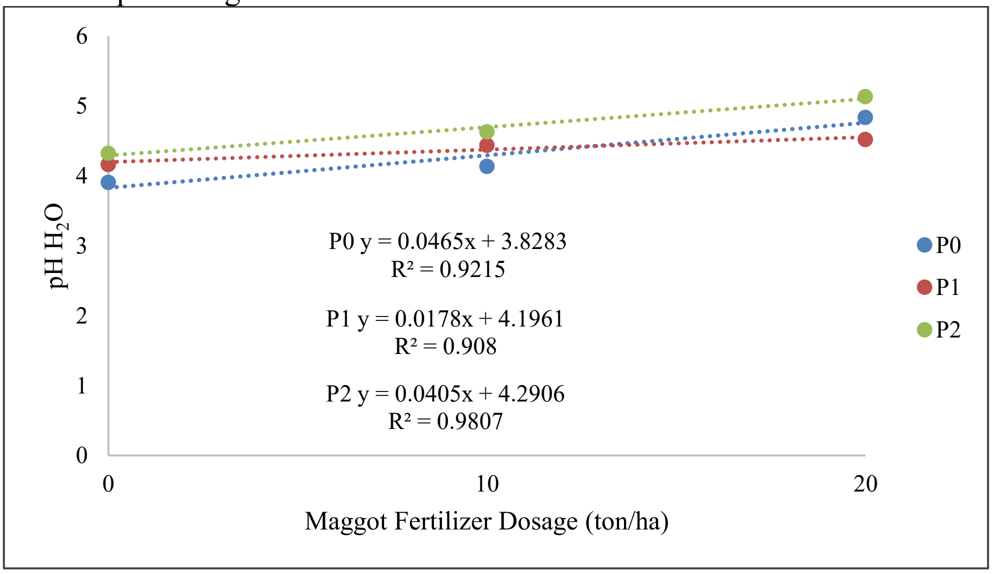

Figure 1. Effect of maggot fertilizer on soil pH H_2O

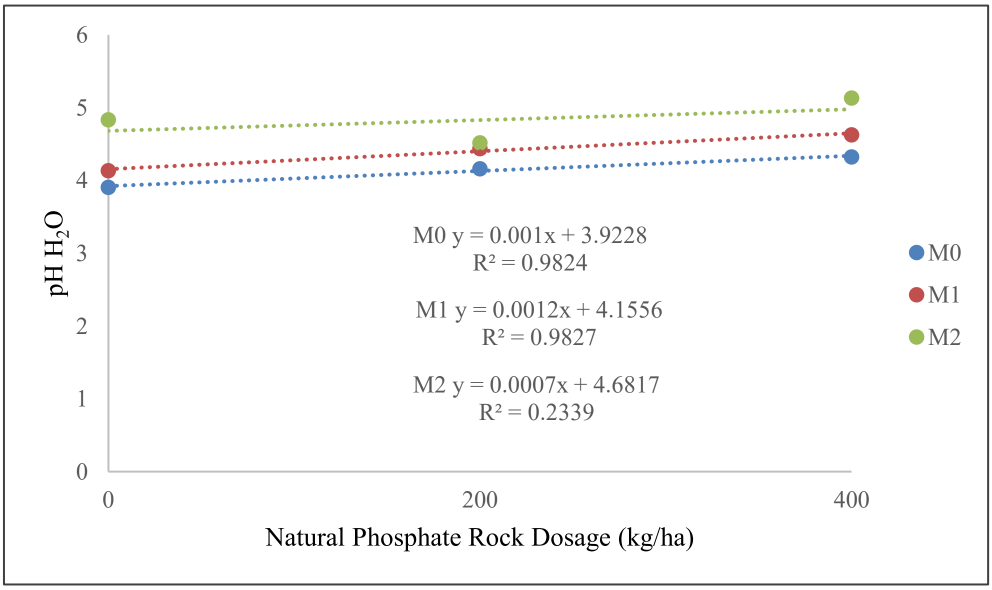

Figure 2. Effect of Natural Phosphate Rock on Soil pH (H_2O)

The best combination for increasing soil pH was observed in the M2P2 treatment, which consisted of maggot fertilizer at 20 tons/ha and natural phosphate rock at 400 kg/ha. The increase in soil pH with the addition of organic materials may be attributed to the production of organic acids such as humic and fulvic acids. These acids can form complexes with toxic elements like Al^{3+} and Fe^{3+}, reducing their availability in the soil through chelation, thereby lowering soil acidity.

Furthermore, the observed interaction between maggot fertilizer and natural phosphate rock may be explained by the fact that organic acids from the fertilizer facilitate the dissolution of phosphate rock. This dissolution process releases OH^- ions which help to neutralize soil acidity and contribute to a rise in pH. The synergistic effect of organic matter and phosphate rock enhances both the buffering capacity and nutrient availability in acidic soils like Red-yellow Podzolic soil.

B. C-Organic

Soil organic carbon (C-organic) represents the carbon component of soil organic matter and plays a vital role in determining soil fertility and quality. C-organic contributes to soil structure, water retention, and nutrient cycling, making it a key indicator of soil health. Variations in C-organic levels are influenced by processes such as decomposition and mineralization, which are in turn affected by soil properties including texture (Augustin & Cihacek, 2016), pH, the presence of metal cations, cation exchange capacity (CEC) (Solly et al., 2019), and nitrogen content. The results of the analysis of variance for C-organic content showed no significant differences and no interaction effect between the application of maggot fertilizer and natural phosphate rock in Red-yellow Podzolic soil (Table 4).

Table 4. Effect of maggot fertilizer and natural phosphate rock on C-Organic content (%)

Maggot Fertilizer	**Natural Phosphate Rock**			**Means**
	P0	**P1**	**P2**	
M0	0.04	0.07	0.04	0.05 p
M1	0.07	0.16	0.08	0.10 p
M2	0.12	0.08	0.10	0.10 p
Means	0.08 a	0.10 a	0.07 a	(-)

Note: Means in the same column or row followed by the same letter are not significantly different based on the 5% DMRT test. A dash (–) indicates no interaction between treatments.

The absence of significant differences in C-organic content across treatment levels may be attributed to the dynamics of microbial activity in the soil. According to (Suryatmana et al., 2020), microorganisms live either in solitary or synergistic consortia, utilizing organic matter (carbon) or other substrates during the mineralization process. This process results in end products such as CO_2 and H_2O. The effectiveness of this microbial activity depends on several factors, including the type of microorganisms present, the quality and composition of the substrate (organic matter), and environmental conditions such as temperature, moisture, and aeration. Once the applied organic fertilizer is fully decomposed, the microorganisms resume utilizing the native organic matter in the soil as their carbon source. Consequently, the continuous microbial decomposition process may limit any further increase in measurable C-organic content, as the organic carbon is eventually converted into CO_2 and lost to the atmosphere. The effect of maggot fertilizer and natural phosphate rock on soil C-organic content is illustrated in Figure 3.

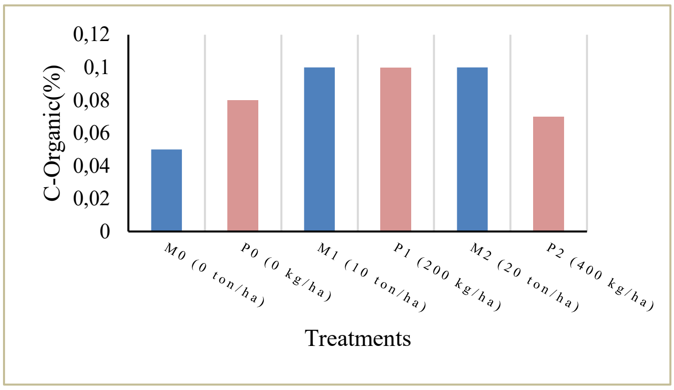

Figure 3. Effect of maggot fertilizer and natural phosphate rock application on soil C-organic content

Based on Figure 3, the highest C-organic content was observed in the M1 treatment, corresponding to the application of maggot fertilizer at a dose of 10 tons/ha. For natural phosphate rock, the highest value was found in the P1 treatment at a dose of 200 kg/ha. However, increasing the dose of organic fertilizer did not linearly increase the C-organic content. This suggests that microbial activity rapidly metabolized the added organic matter, converting it into CO_2, thereby limiting the accumulation of C-organic in the soil.

C. N-Total

Nitrogen (N) is a macronutrient that plants require in large quantities to support vegetative growth and metabolic functions. Plants absorb nitrogen primarily in the form of nitrate (NO_3^-) and ammonium (NH_4^+). However, nitrate is quickly reduced to ammonium in plant tissues through enzymatic processes involving molybdenum-dependent enzymes. The results of the analysis of variance for the N-total parameter showed no significant differences and no interaction between the application of maggot fertilizer and natural phosphate rock in increasing total nitrogen content in Red-yellow Podzolic soil (Table 5).

Table 5. Effect of maggot fertilizer and natural phosphate rock on N-Total (%)

Maggot Fertilizer	**Natural Phosphate Rock**			**Means**
	P0	**P1**	**P2**	
M0	0.27	0.28	0.25	0.27 p
M1	0.29	0.25	0.25	0.26 p
M2	0.34	0.28	0.29	0.31 p
Means	0.30 a	0.27 a	0.27 a	(-)

Note: Means followed by the same letter in the same row or column are not significantly different based on the 5% DMRT test. A dash (–) indicates no interaction between treatments.

The lack of significant treatment effects on total nitrogen content could be attributed to limited nitrogen availability under certain conditions, such as nitrogen fixation or immobilization processes. The influence of organic maggot fertilizer and natural phosphate rock application on N-total is shown in Figure 4.

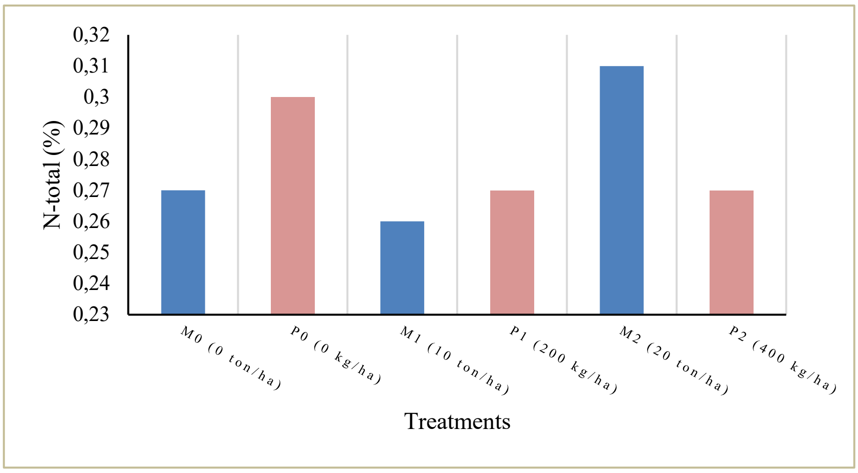

Figure 4. Effect of maggot fertilizer and natural phosphate rock on N-Total (%)

The highest total nitrogen content was observed in the M2 treatment, corresponding to the application of 20 tons/ha of maggot fertilizer. Meanwhile, the highest N-total value in the natural phosphate rock treatment was found in the P0 treatment (no phosphate application). This is expected as natural phosphate rock does not contain nitrogen and therefore does not directly contribute to increasing N levels in the soil. According to (Hakim et al., 2011), the application of organic matter to soil initiates decomposition processes that release nitrogen. Organic matter is broken down by soil microbes through a sequence of reactions: aminization (conversion to amine compounds), ammonification (conversion to ammonium), and nitrification (conversion to nitrate). These processes gradually release nitrogen into the soil, improving nutrient content even in degraded soils such as ex-mining Podsolic soils.

Furthermore, the increase in N-total following organic matter application may also be supported by a rise in soil pH although relatively minor (Rahmah et al., 2014). Conversely, the observed decline in total N in the M1 treatment (10 tons/ha) might be due to nitrogen loss through leaching or volatilization. Nitrogen in the nitrate (NO_3^-) form is highly soluble, mobile in the soil, and not retained by soil colloids. It can be lost as gas through denitrification, where nitrate is reduced to nitrogen gases (N_2 and N_2O) (Cesaria et al., 2014).

D. Available P

Phosphorus (P) is an essential macronutrient required in large quantities for optimal plant growth and development. It plays a vital role in soil fertility, photosynthesis, and plant physiological processes. In particular, phosphorus is crucial for cell division, tissue development, and the formation of plant meristems (Widarti et al., 2015). The results of the analysis of variance for available P showed no significant interaction between the application of maggot fertilizer and natural phosphate rock on the available phosphorus content in Red-yellow Podzolic soil (Table 6).

Table 6. Effect of maggot fertilizer and natural phosphate rock on available P (ppm)

Maggot Fertilizer	**Natural Phosphate Rock**			**Means**
	P0	**P1**	**P2**	
M0	0.62	4.12	3.62	2.79 p
M1	5.96	10.14	9.58	8.56 q
M2	15.81	16.56	18.65	17.00 r
Means	7.46 a	10.27 b	10.62 b	(-)

Note: Means followed by the same letter in the same row or column are not significantly different based on the 5% DMRT test. A dash (–) indicates no interaction between treatments.

Although there was no interaction between the two factors, a significant difference was observed in the individual treatment levels. The application of maggot fertilizer showed significant differences among dosage levels, while for natural phosphate rock, significant differences were found between the P0 and P2 treatments. Compared to the initial soil condition before treatment, the application of both maggot fertilizer and natural phosphate rock increased the available phosphorus content in the soil.

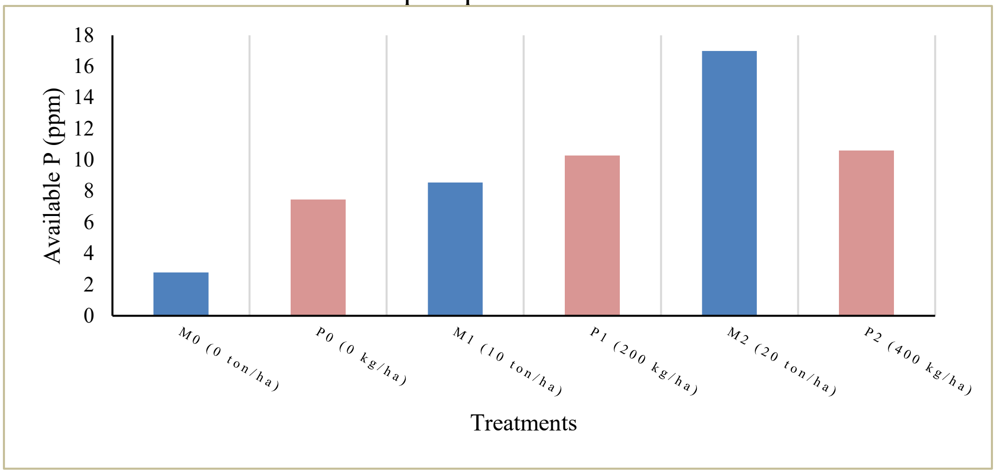

Figure 5. Effect of maggot fertilizer and natural phosphate rock application on available P

The highest available P content was recorded in the M2 treatment (maggot fertilizer at 20 tons/ha), while in the phosphate rock treatment, the highest value was found in P2 (natural phosphate at 400 kg/ha). The increase in phosphorus availability with increasing dosage is primarily due to enhanced mineralization processes. the addition of organic matter improves phosphate solubility in the soil. Organic inputs, such as maggot fertilizer, contribute to displacing phosphorus that is otherwise bound to Al and Fe oxides, thus making it more available for plant uptake.

Additionally, the decomposition of organic matter by soil microorganisms leads to the production of phosphatase enzymes, which are responsible for converting organic phosphorus into inorganic forms that are readily absorbed by plant roots and soil microbes. The application of natural phosphate rock, particularly apatite ($Ca_5(PO_4)_3$), also contributes to increasing available phosphorus. In acidic conditions, apatite reacts with H^+ ions to form $Ca(H_2PO_4)_2$, a more soluble form of phosphate that can be utilized by plants. As the dosage of natural phosphate rock increases, the quantity of available P also rises, supporting the trend observed in the study.

E. Available K

Potassium (K) is one of the essential macronutrients that significantly supports plant growth and development. It plays a critical role in various physiological processes, including photosynthesis, transpiration, enzyme activation, and the regulation of water and nutrient transport within the plant (Cahyaningsih, 2019). In the soil, potassium also contributes to maintaining optimal pH levels, enhancing cation exchange capacity (CEC), and promoting the decomposition of organic residues. The analysis of variance for the available K parameter showed no significant interaction between the application of maggot fertilizer and natural phosphate rock in increasing the available potassium content of Red-yellow Podzolic soil (Table 7).

Table 7. Effect of maggot fertilizer and natural phosphate rock on Available K (ppm)

Maggot Fertilizer	**Natural Phosphate Rock**			**Rerata**
	P0	**P1**	**P2**	
M0	7.58	8.71	8.12	8.13 p
M1	17.03	16.90	16.43	16.78 q
M2	18.21	18.11	17.60	17.97 q
Means	14.27 a	15.46 a	14.05 a	(-)

Note: Means followed by the same letter in a column or row are not significantly different based on the 5% DMRT test. A dash (–) indicates no interaction between treatments.

Although there was no interaction between the two treatment factors, significant differences were observed in the maggot fertilizer treatment. Specifically, the available K content in the M0 treatment (no fertilizer) was significantly lower than in the M2 treatment (20 tons/ha). On the other hand, the application of natural phosphate rock did not result in significant differences across all treatment levels. The effect of maggot fertilizer and natural phosphate rock application on available K is illustrated in Figure 6.

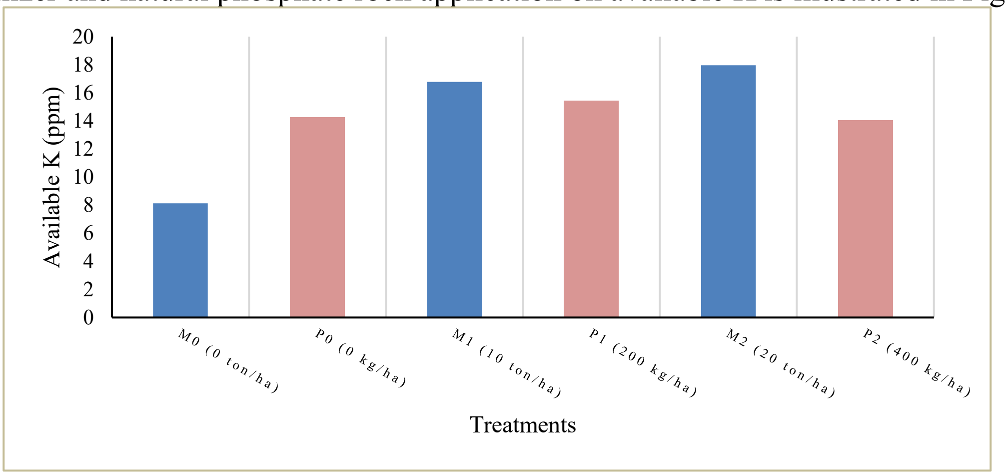

Figure 6. Effect of maggot fertilizer and natural phosphate rock application on available K

The highest available K content was found in the M2 treatment, corresponding to the application of 20 tons/ha of maggot fertilizer. For natural phosphate rock, the highest value was recorded in the P1 treatment with a dose of 200 kg/ha. The observed increase in available K with increasing doses of maggot fertilizer may be associated with improvements in soil pH. According to (Harefa and Meiman.2024), a reduction in soil acidity or an increase in alkalinity typically enhances the availability of exchangeable cations such as K^+, Ca^{2+}, Na^+, and Mg^{2+}.

The decomposition of maggot-based organic matter by soil microorganisms plays a vital role in this process. Potassium present in organic form within maggot cell structures is released into the soil as inorganic, plant-available K through microbial breakdown. The variation in potassium levels may also be influenced by the rate at which microorganisms decompose organic matter during the fermentation and mineralization process (Mulyadi et al., 2013).

According to research results by Kesumaningwati et al., (2023), the weight, quantity, and height of hybrid mustard greens plants are also impacted by the administration of maggot fertilizer. A very significant effect was shown in the P3 treatment with a fertilizer dose of 75 grams/polybag.

CONCLUSION

Application of organic fertilizer from maggot livestock waste increased available P and K, while natural phosphate rock improved available P compared to untreated soil. The combination of maggot fertilizer (20 tons/ha) and natural phosphate rock (400 kg/ha) showed a significant interaction in raising soil pH H_2O. The M2P2 treatment was the most effective in improving soil pH and nutrient availability in red-yellow Podsolic soil.

REFERENCES

Augustin, C., & Cihacek, L. J. (2016). Relationships Between Soil Carbon and Soil Texture in the Northern Great Plains. *Soil Science*, *181*(8), 386–392. https://doi.org/10.1097/SS. 0000000000000173

Cahyaningsih, F. I. (2019). *Keseimbangan Pemupukan Nitrogen Dan Kalium Pada Pertumbuhan Dan Hasil Tanaman Kailan (Brassica oleracea L.)*. Universitas Brawijaya.

Cesaria, R. Y., Wirosoedarmo, R., & Suharto, B. (2014). Pengaruh Penggunaan Starter Terhadap Kualitas Fermentasi Limbah Cair Tapioka Sebagai Alternatif Pupuk Cair. *Jurnal Sumberdaya Alam Dan Lingkungan*, *1*(2), 8–14.

Manullang, D. W. S., Gusmini, & Rezki, D. (2021). Karakteristik Sifat Kimia Tanah Dan Kandungan Merkuri Pada Lahan Bekas Tambang Emas Dan Lahan Perkebunan Kelapa Sawit (Elaeis guineensis Jacq.). *Jurnal Riset Perkebunan*, *2*(1), 1–11. https://doi.org/10.25077/jrp.2.1.1-11.2021

Gärdenäs, A. I., Ågren, G. I., Bird, J. A., Clarholm, M., Hallin, S., Ineson, P., Kätterer, T., Knicker, H., Nilsson, S. I., Näsholm, T., Ogle, S., Paustian, K., Persson, T., & Stendahl, J. (2011). Knowledge gaps in soil carbon and nitrogen interactions – From molecular to global scale. *Soil Biology and Biochemistry*, *43*(4), 702–717. https://doi.org/10.1016/j.soilbio. 2010.04.006

Hakim, N., Yanti, M., & Rozen, N. (2011). *Uji Multi Lokasi Pemanfaatan Pupuk Organik Titonia Plus untuk Mengurangi AplikasiPupuk Buatan (50%) dalam Meningkatkan Produksi Padi pada Sawah Bukaan Baru di Kabupaten Dharmasraya. Laporan Hasil Penelitian KKP3T Tahun III*. Kerjasama Universitas Andalas dengan Sekretariat Badan Penelitian Tanah dan Pengembangan Pertanian.

Hardjowigeno, S. (2015). *Ilmu Tanah*. Akademika Pressindo.

Harefa. D. F. C and Meiman Zebua. 2024. Peran Kapasitas Tukar Kation Dalam Mempertahankan Kesuburan Tanah Pada Berbagai Jenis Tekstur Tanah. Jurnal Ilmu Pertanian dan Perikanan ISSN 3063-6469 (E) Volume 01, Nomor 01.

Kesumaningwati. R, Surya Darma, Noor Muhammad Ramadhan. 2023. Application Of Maggot Fertilizer To Plant, Soil Chemical Properties Development and Production of Sawi Hibrida (Brassica juncea L). Jurnal Agroekoteknologi Tropika ISSN: 2622-3570 Volume 5, Nomor 2, Februari 2023 E-ISSN:2621-394X Halaman : 84-91 DOI.210.35941/JATL

Mulyadi, Y., Sudarno, S., & Sutrisno, E. (2013). Studi Penambahan Air Kelapa Pada Pembuatan Pupuk Cair Dari Limbah Cair Ikan Terhadap Kandungan Hara Makro C, N, P, Dan K. *Jurnal Teknik Lingkungan*, *2*(4), 1–14.

Nirmala, W., Purwaningrum, P., & Indrawati, D. (2020). Pengaruh Komposisi Sampah Pasar Terhadap Kualitas Kompos Organik Dengan Metode Larva Black Soldier Fly (Bsf). *Prosiding Seminar Nasional Pakar*. https://doi.org/10.25105/pakar.v0i0.6807

Rahmah, Yusran, & Husain. (2014). Sifat Kimia Tanah pada Berbagai Tipe Penggunaan Lahan di Desa Bobo Kecamatan Palolo Kabupaten Sigi. *Warta Rimba*, *2*(2).

Solly, E. F., Weber, V., Zimmermann, S., Walthert, L., Hagedorn, F., & Schmidt, M. W. I. (2019). *Is the content and potential preservation of soil organic carbon reflected by cation exchange capacity? A case study in Swiss forest soils*. https://doi.org/10.5194/bg-2019-33

Suryatmana. P., Mahdi Argawan Putra., Nadia Nuraniya Kamaluddin., Mieke Rochimi Setiawati., Betty Natalie Fitriatin ., dan Reginawanti Hindersah. 2021. Efek Inokulasi Konsorsium Mikroba dan Aplikasi Nutrisi terhadap Populasi Azotobacter spp, Serapan N, Pertumbuhan Tanaman dan Hasil Tomat (Solanum lycopersicum L.) pada Sistem Hidroponik. Soilrens, Volume 19 No. 1.

Tian. D., Liyan Wang, Jun Hu., Liangliang Zhang., Ningning Zhou., Jingjing Xia., Meiyue Xu., Kianpoor Kalkhajeh Yusef., Shimei Wang., Zhen Li., and Hongjian Gao. 2021. A study of P release from Fe-P and Ca-P via the organic acids secreted by Aspergillus niger. Journal of Microbiology (2021) Vol. 59 DOI 10.1007/s12275-021-1178-5

Widarti, B. N., Wardhini, W. K., & Sarwono, E. (2015). Pengaruh Rasio C/N Bahan Baku pada Pembuatan Kompos dari Kubis dan Kulit Pisang. *Jurnal Integrasi Proses*, *5*(2), 75–80.