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Soil Fertility Status, Nutrient Uptake, And Soybean Yield Following Organic^{PLUS} Fertilizer Application On Alfisol

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ABSTRACT
This study aims to assess the impact of Organic Fertilizer^{Plus} on soil fertility status, nutrient uptake, and soybean yield in Alfisol. The research employs a randomized complete group design (RCGD) with a single factor, consisting of P0 (Control), P1 (Cow dung, 5 tons ha^{-1} + Zeolite dose of 2.5 tons ha^{-1}), P2 (Cow dung, 5 tons ha^{-1} + Zeolite dose of 5 tons ha^{-1}), P3 (Cow dung, 5 tons ha^{-1} + Dolomite dose of 2.5 tons ha^{-1}), P4 (Cow dung, 5 tons ha^{-1} + Dolomite dose of 5 tons ha^{-1}), and P5 (Cow dung, 5 tons ha^{-1} + Zeolite dose of 5 tons ha^{-1} + Dolomite dose of 5 tons ha^{-1}), repeated four times. The results indicate that the application of Organic FertilizerPlus enhances soil fertility status (pH, organic C, CEC, and available P), with the highest values observed in treatment P5, including pH (6.70), soil organic C (6.28 g.kg^{-1}), cation exchange capacity (CEC) (6.85 cmol.g^{-1}), and available P (2.63 mg.g^{-1}). This leads to increased phosphorus uptake, consequently improving soybean yields. The highest soybean yield is achieved by applying Organic FertilizerPlus (P5) at 2.17 t.ha^{-1}.

Key words: Cow dung; Dolomite; P uptake; Soil pH; Zeolite
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INTRODUCTION

The program to increase soybean production can be done through extensification efforts by utilizing marginal lands. One of the potential areas is Alfisols soil. Alfisols are soils with the third largest area in the world, with a distribution of almost 10% of the earth's surface area (Fiantis, 2017). In Indonesia, alfisols have an area of 12,749,000 hectares (Supriyono et al., 2022). Alfisols are soils that have undergone intensive weathering and advanced development (Ayal et al., 2017) and generally have low chemical fertility, which becomes an obstacle in its development (Nusantara et al., 2014), such as acid soil reaction, low CEC, low base saturation, low organic matter, and macronutrient deficiencies (Sanchez, 1992).

One essential macro-nutrient very low in Alfisol is Phosphorus (P) (Syamsiyah et al., 2023). In the tropics, P is estimated to be the third limiting factor for plant growth and production after water and nitrogen. The total amount of P is adequate, but what is available to plants in most soils is generally low, the P absorbed by plants from fertilizers is only around 8 - 20%, and the rest is absorbed by the soil (Tisdale *et al*., 1985), It is further explained that the application of inorganic phosphorus fertilizers to increase the amount of phosphorus that can be utilized by plants is considered less effective, because it is only available and can be absorbed by plants around 8-13%, the rest is converted into insoluble phosphates that cannot be absorbed by plants.

Improvement of soil chemical properties needs to be done to increase its fertility, including by using organic fertilizer plus, which is (a mixture of Cow dung with ameliorants in the form of Zeolite and Dolomite minerals) and is expected to increase the productivity of Alfisols to improve growth and increase soybean yields. Several studies have shown the real role of organic fertilizers in increasing the availability of P in the soil, such as those conducted by Lukiwati dan Pujaningsih (2014), that manure residues enriched with natural phosphate and inoculated with microbial decomposers can produce higher phosphate than without biodecomposers. Research results Nurhayati et al. (2014) show that the provision of various types of ameliorants, such as lime, seaweed, and several types of soil microorganisms, affects the soil pH so that it will spur the decomposition process of organic matter, which produces organic phosphate compounds which can then be converted into inorganic phosphate through a complete decomposition process.

Organic^{plus} fertilizer (a mixture of Cow dung with ameliorants in Zeolite and Dolomite minerals) can provide multiple benefits, increasing soil and plant productivity. Manure improves soil physical and chemical properties, including increasing cation exchange capacity, acting as a buffer against unwanted variations in soil pH, and providing the necessary plant nutrients (Faissal et al., 2017). Dolomite contains Ca+ (CaO) and (MgO) with high enough levels will provide an alkaline effect so that the pH of the soil increases. According to Juarsah (2016) dolomite can temporarily hold nutrients from fertilizers so that they are not lost due to washing and can be rereleased to be absorbed by plants. Dolomite in both organic and mineral forms can be applied not only to dry soils but also to paddy fields, while Zeolite is an aluminosilicate crystal mineral that has the ability to absorb and exchange ions and buffer pH (Ridho et al 2014, Sabilu 2016). The study aimed to determine the effect of Organicplus fertilizer (a mixture of Cow dung with ameliorants in the form of Zeolite and Dolomite minerals) on soil fertility and nutrient uptake on soybean yield in alfisol soil The synergistic effect of these components is expected to improve soil fertility, enhance nutrient availability, and ultimately boost crop yields. This innovative approach represents a holistic strategy for optimizing the benefits of organic and mineral inputs in agricultural practices.

MATERIAL AND METHODS

This research was conducted in Sukosari Village, Jumantono District, Karanganyar Regency, on Alfisol soil from February 2023 to July 2023. Soil and plant analysis were conducted at the Laboratory of Chemistry and Soil Fertility FP UNS. The study used a single-factor Randomized Complete Group Design (RAKL) consisting of six treatments, namely P0 (Control). P1 (Cow dung, dose of 5 ton ha^{-1} + Zeolite dose of 2.5 ton ha^{-1}), P2 (Cow dung 5 ton ha^{-1}+ Zeolite 5 ton ha^{-1}), P3 (Cow dung 5 ton ha^{-1}+ Dolomite 2.5 ton ha^{-1}), P4 (Cow dung 5 ton ha^{-1}+ Dolomite 5 ton ha^{-1}), P5 (Cow dung 5 ton ha^{-1} + Zeolite 5 ton ha^{-1} + Dolomite 5 ton ha^{-1}) with four replications so that 24 experimental units were obtained. Local soybean varieties were planted with a spacing of 20 x 25 cm on 2 m x 1 m plots.

Soil analysis carried out includes pH with a ratio of 1: 2 (soil: water mixture) (Potentiometry) (Atih Winingsih et al., 2019), C-organic (Walkey and Black) (Harahap et al., 2021), Cation Exchange Capacity (CEC) (NH_4Oac pH 7.0 Saturation) (Suryani & Hikmatullah, 2015), Available P using the Bray I method for early soil (pre-planting) and the Olsen method for the generative phase (harvesting) (Balittanah, 2009; Umaternate et al., 2014). Plant analysis included P uptake, number of soybean pods, and 100 seed weight. The observed data were analyzed using Analysis of Variance (ANOVA) with a 95% confidence level and Duncan's Multiple Range Test (DMRT) to compare means between treatments..

RESULT AND DISCUSSION

From the initial analysis of Alfisol soil chemical properties, the results obtained (Table. 1), pH H_2O is slightly acidic (5.9), low soil organic C (1.65%), moderate CEC (20.47 mg.Kg-1) and low P-available nutrients (4.67 mg. Kg -1), based on the main guidelines from the Soil Research Center (1981) on estimating land suitability, especially soil fertility (pH, CEC, soil organic C and available P), the Alfisol soil fertility of the experiment is in the low to moderate category (Rosmakan & Yuwono, N, 2002). Low amounts of available phosphorus can be a major nutrient that limits plant growth and is unfavorable to plants (Maryani, 2018). Suryono et al. (2012) stated that the ability of Alfisol to provide nutrients for plants is low, so one way to improve and increase Alfisol soil fertility is by adding fertilizer. The provision of organic plus fertilizer (a mixture of Cow dung with ameliorants in the form of Zeolite and Dolomite minerals) is expected to play a role in creating a good soil environment for plant growth because it is able to improve the balance of physical, chemical, and biological properties of the soil so that it will be able to increase the efficiency of nutrient uptake.

Table 1. Result of Initial Soil Characteristic Analysis and Organic^{PLUS} Fertilizer

Chemical Characteristics	Soil	Cow dung	Dolomite	Zeolite
pH H_20	5.9	7.3	7.1	8.1
C-organic ($g.kg^{-1}$)	1.65	4.24		
CEC ($cmol.kg^{-1}$)	20 47			128.60
C/N Ratio	4.42	13.2		
P available ($mg.kg^{-1}$)	4.67	0.31		
Ca ($cmol.kg^{-1}$)	1.74	0.56	21	
Mg ($cmol.kg^{-1}$)	0.44	0.87	10.8	

Description: Primary Data

The organic^{plus} fertilizer used in this study has a C/N ratio of Cow dung of 13.2 with an organic C value of 4.24%, which is relatively high to supply the availability of nutrients in the soil and has met the C/N ratio criteria for application based on the Indonesian Ministry of Agriculture Regulation no 261 of 2019, namely the C/N value ≤ 25 (Persyaratan Teknis Minimal Pupuk Organik, Pupuk Hayati, Dan Pembenah Tanah, 2019). Cow dung with a C/N of 13.2 shows a high level of decomposition so that the rate of mineralization of nutrients is quickly available to plants. The CEC value in Zeolite is 128.60 % me/100g (Table 1), has met the criteria of technical requirements of the regulation of the minister of agriculture of the Republic of Indonesia number 70 with the CEC of Zeolite which is at least 120 me/100g. Dolomite, with a pH value of 7.1, shows a neutral value with Ca and Mg dolomite content of 21% and 10.8%. This affects the increase in soil pH to increase the availability of P by freeing P from absorbing cation bonds.

Effect of Treatment on Soil Variables

T he DMRT test result s of the effect of the treatment of organic^{plus} fertilizer (a mixture of Cow dung + Zeolite + Dolomite) on the observed soil variables gave the results as shown in (Table 2).

Table 2. Effect of Treatment on Soil Variabel

Treatment	pH	Soil organic C (g.kg-1)	Cation Exchange Capacity (CEC) (cmol.kg-1)	P available (mg.kg-1)
P0	6,27 a	1,30 a	17.69 a	2,06 a
P1	6,37 a	1,45 a	26.98a	2,18 ab
P2	6,41 a	1,75 a	30.94bc	2,29abc
P3	6,66 b	2,87 b	39.07cd	2,40 abc
P4	6,68 b	4,27 c	39.73d	2,48 bc
P5	6,73 b	6,26 d	44.95d	2,61 c

Note: Results followed by the same letter indicate insignificant differences in the 5% DMRT analysis

From the analysis of soil pH, there was an increase in all treatments compared to the control. The highest value was obtained in treatment P5 (6.73), and the lowest pH value was obtained in the control treatment P0 (6.27). This can be caused by the mixture of cow dung from organic^{plus} fertilizer, which, when applied to the soil, will decompose, releasing minerals in the form of basic cations, thus increasing the concentration of OH^- ions and resulting in an increase in pH value (Yuniarti et al., 2020). In addition, the addition of Dolomite in treatments P3, P4, and P5, which contains Ca and Mg elements, will affect the increase in pH in the soil because both factors can release OH- ions through hydrolysis reactions to neutralize H + ions from the soil solution (Ilham et al., 2019). Zeolite, as a mixture in organic^{plus} fertilizer, is also an aluminosilicate crystal mineral that can absorb and exchange ions and buffer the pH of the soil (Ridho et al. 2014, Sabilu 2016). Organic C, CEC, and P-available levels also increased due to applying organic^{plus} fertilizer. This shows an interaction between Cow dung, Zeolite, and Dolomite in helping to increase organic matter, CEC, and P-available levels.

The highest C-organic results were found in treatment P5 (6.26 g.kg^{-1}), with the lowest results found in P0 (1.30 g.kg-1). The highest CEC value was also obtained in treatment P5 (65.83 cmol. kg^{-1}) and the lowest in P0 (23.06 cmol. kg^{-1}) (Table 2). Associated with an increase in soil organic C, Syahputra et al. (2015) said that the application of compost and dolomite fertilizer had a significant effect on soil organic C. In line with the research of Adeniyan et al. (2011), which showed that the application of 5 t ha-1 manure significantly increased pH, organic C, CEC, and available P. Nusantara et al. (2014) added that Ca content can increase CEC so that it can reduce the reactivity of Al and Fe in fixating P and P becomes available. This can be seen from the results of available P, where the treatment given organic^{plus} fertilizer increased available P in the soil. The highest available P value was obtained in treatment P5 (2.61 mg.kg^{-1}) and the lowest in control P0 (2.06 mg.kg^{-1}). During the mineralization process from the application of manure and Dolomite, there will be a release of P in the soil, which continues to increase over time. The Ca and Mg content of dolomite can increase soil pH, which will stimulate the decomposition of organic matter to produce organic phosphate compounds. Additionally, organic phosphate compounds can be converted to inorganic phosphates through a more complete decomposition process. (Firdany et al., 2021; Maerere et al., 2001; Nurhayati et al., 2014).

The increase in P availability by applying organic fertilizer is believed to affect the growth and yield of soybean plants. As explained by Chimdi (2012) increasing soil pH can release unavailable P that was previously fixed by Al and Fe in low soil pH conditions. Precipitated phosphate ions are released into the soil solution, thus making phosphate ions available for plant absorption. pH is the main factor that will affect activity in the soil (Karamina et al., 2018). The results showed that the pH of Alfisol from applying organic^{plus} fertilizer increased from initially acidic to near neutral and affected the availability of P in Alfisol soil (Table 3).

Table 3. Effect of Soil pH on available P-soil

Treatment	pH	P available (mg.kg^{-1})
P0	6,27^{a}	2,06^{a}
P1	6,37^{a}	2,18^{ab}
P2	6,41^{a}	2,29^{abc}
P3	6,66^{b}	2,40^{abc}
P4	6,68^{b}	2,48^{bc}
P5	6,73^{b}	2,61^{c}

Note: Results followed by the same letter indicate insignificant differences in the 5% DMRT analysis.

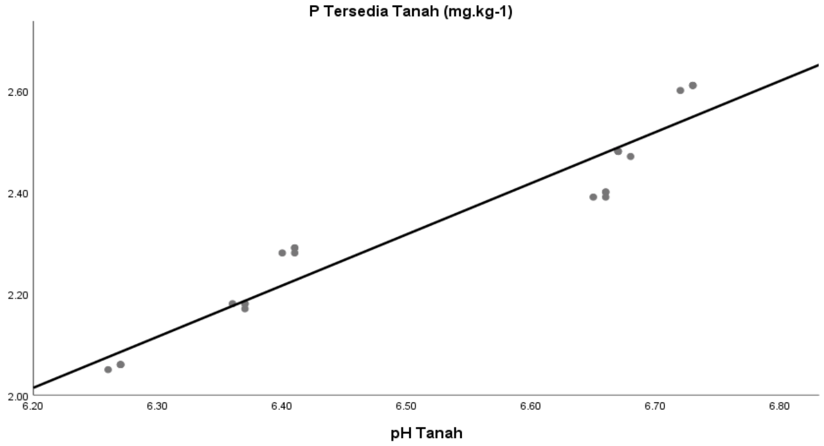

Figure 1. Relationship between soil pH and soil P-availability

From the regression analysis results, the coefficient of determination was obtained (R^2 = 0.925), which means that soil pH has an effect of 92.5% on the availability of P in the soil. These results show a positive relationship between soil pH and P availability (r = 0.962). Miller J.O (2016) stated in his research that increasing pH will encourage the process of soil activity to be optimal. Zhang et al. (2019) confirmed that soil pH will control soil nutrient availability, soil microbial activity, and plant growth and development.

Soybean is known as a plant that requires phosphorus (P) in sufficient amounts between 0.25 - 0.50 ppm (Reuter dan Robinson, 1986). Phosphorus is needed mostly in the vegetative phase for plant growth and then stored in the form of seeds/pods in the generative phase (FAO, 2004). Previous studies have shown that P uptake increases with increasing phosphorus levels in the soil (Devi et al., 2012). The analysis of variance showed that the application of organicplus fertilizer significantly affected the uptake of P nutrients, the number of pods per plant, and soybean yield (Table 4).

Table 4. Effect of treatments on P uptake, number of pods per plant and yield of soybean

Treatment	P uptake	Number of pods per plant	Yield of soybean (ton/ha)
P0	2,3 ᵃ	22 ᵃ	1,64 ᵃ
P1	3,6 ab	28 ab	1,82 b
P2	4,19 ab	37 ab	2,38 ab
P3	4,59 ab	39 bc	2,01 ab
P4	4,72 ab	39 bc	2,03 ab
P5	5,23 ab	42 c	2,17 ab

Note: Results followed by the same letter indicate insignificant differences in the 5% DMRT analysis

The highest increase in P uptake and soybean yield was found in the P5 treatment (Cow dung, dose of 5 tons ha-1 + Zeolite dose of 5 tons ha-1 + Dolomite dose of 5 tons ha-1) of 5.23 mg/plant with 42 pods per plant, while the lowest uptake was in the control treatment of 2.3 mg/plant with 22 pods per plant. These results are in line with the research of Sudarsono et al. (2013) that the application of Cow dung as much as 7.5 tons/ha can increase P uptake by 41.78% compared to the control treatment. Manshuri (2010) also showed that with a lot of nutrient supply, nutrient uptake, and accumulation will also be high. Increased P uptake in alfisols will affect soybean yields. Supporting this statement, Maryanto dan Abubakar (2010) found that P uptake is influenced by available P in the soil and the ability of root growth to absorb nutrients. Table 4 shows that P5 produces the highest number of soybean pods that are significantly different from the other treatments. These results also confirm the research of Devi et al. (2012) that the level of P in the soil determines the yield of soybean because legume plants require a relatively high amount of P for growth and N fixation and with the increase in the number of soybean pods it will increase soybean yield or it can be interpreted that P uptake has a significant effect on the number of pods and soybean yield.

CONCLUSION

Overall, the results showed that the application of organicplus fertilizer was proven to improve soil fertility status and soybean yields in Alfisol. The increase in soil fertility is shown from the increased chemical characteristics of Alfisol soil, namely (soil pH, organic C, CEC, available P, and P uptake), with the highest results in the provision of P5 organicplus fertilizer (mixture of Cow dung, dose of 5 tons ha^{-1}+ Zeolite dose of 5 tons ha^{-1}+ Dolomite dose of 5 tons ha^{-1}) namely pH (6. 70), soil organic C (6.28 $g.kg^{-1}$), cation exchange capacity (CEC)

(6.85 cmol.g-1), available P (2.63 mg.g-1) while the highest increase in soybean yield was in the same organic fertilizer P5 of (2.17 t ha^{-1}).

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