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THE EFFECT OF STEEL SLAG AND RICE HUSK BOKASHI ON P RETENTION, AVAILABLE P AND SWEET CORN BIOMASS ON ANDISOLS

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ABSTRACT

Steel slag and rice husk bokashi are the ameliorant that expected can decrease P-retention increase available P in Andisols. The objective of this research was to compile the influence of steel slag and rice husk bokashi to P-retention, available P and corn biomass. The treatments were arranged in Randomized Block Designed in factorial pattern with two factors: steel slag and rice husk bokashi, each consisted of four level: 0, 2.5, 5.0 and 7.5 % in 10 kg soil weight (w/w), made 16 combined treatments and repeated three times. The treatments were incubated for four months and then be analyzed the soil characteristics. The results showed that. Slag steel and rice husk bokashi did not interact in decreasing P-retention and increasing available P, but 7.5% of rice husk bokashi individually decreased P-retention to 84.58% and increased available P to 254.75 ppm P. Slag steel and rice husk bokashi interacted in increasing corn biomass, where the combination of 2.5% and 5.0% steel slag with 7.5% rice husk bokashi resulted in biomass of 170.73 g and 217.68 g.

Keywords: Soil Phosphorus, Volcanic Ash Soils, Silicon.

1. INTRODUCTION

Andisols are soils develop by weathering of volcanogenic materials (James et al., 2000). They are found across various climates and cover about 1.8% of land on earth (Eswaran and Reich, 2005). Indonesia with a high number of volcanoes, the coverage of Andisols extent about 5.39 million ha, or around 2.9% of the area (Musa et al, 2006), and mostly distributed around the volcanoes. Even though they aren't many, they can support the human need of food, fiber and forage due to their well soil fertility characters like high water holding capacity, low bulk density, high porosity, high cation exhange capacity, and high total-P content (Ugolini and Dahlgren, 2002). Knowing as soils with high total P content, they result in low available P due to their high P-retention that 85% or more (Takahashi and Dahlgren, 2015). Andisols have high short ranged order minerals like allophane, imogolite and ferrihydrite that contribute to that high P-retention. (Amal, 2013).

High P-retention and low available P are serious problem in Andisols (Yatno and Zauyah, 2005; Escudey et al., 2007). Decreasing productivity are caused to this case, but adding P fertilizer is not the solution due to it will be quickly retained by the high amorphous minerals in their clay content (Sachez, 2019). Solving this problem can be done by adding the materials with high negative charge that can replace P from the retention side of the amorphous minerals

(Qafoku et al, 2004). Silicate (SiO_4^{-4}) and organic matters are the material with high negative charge that expected can block the positive charge of of Andisols, decrease the P-retention and increase available P (Van Ranst, 2006).

Steel slag can be used as ameliorant in decreasing P-retention. Silicate content in steel slag can replace retained P in the soils and increase available P (Deus et al., 2018). Steel slag also functioned as fertilizer due to containing some oxide like P_2O_5, CaO, SiO_2, MgO, FeO and MnO that can release some essential nutrient in the soil like P, Ca, Mg, Fe and Mn respectively (Suwarno, 2010). Some bases like Ca and Mg also can increase the soil pH (Ning et al., 2016).

Organic matter fermented as bokashi can be used as soil ameliorant (Christel, 2017). Rice husk bokashi is one of bokashi that was proceeded from rice husk composting by adding the bioactivator. Rice husk bokashi contained about 17% silicate, adding the negative charge to the soil (Anda and Shamshuddin, 2015). The effect of steel slag and rice husk bokashi on P-retention and available P and other chemical characteristics was studied, also their influences to the biomass of sweet corn in Andisols.

2. METHODS

The research was conducted in the field as a pot experiment using Andisols derived from the eruption of Mt. Tangkuban Parahu, Lembang-West Java-Indonesia. Other material used were steel slag, rice husk bokashi, and sweet corn Talenta (*Zea mays* saccharate Sturt). Several chemical compounds were use in laboratory for analyzing the observed parameters

The soils were collected from an adjacent area in several spot in Lembang referred to Geological Map of Silitonga (2003) with Qyd legend or quarter young dano, in 0-20 cm depth and mixed compositely to have the homogeneity to be prepared for the treatments. The steel slag was obtained from PT. Krakatau Steel, Indonesia, that had been grinded into granular. The granul steel slag was then pulverized to 200 mesh size in the Laboratory of Mineral and Coal Technology, Bandung. Bokashi was made from rice husk that had been composted by adding Effective Microorganism 4 (EM4) consisting of *Lactobacillus sp*, photosynthetic bacteria, *Streptomyces* and yeast.

The soil, steel slag and bokashi were analyzed before using for this research. Analyzing of soils and bokashi were done in the Laboratory of Chemistry and Soil Fertility in Faculty of Agriculture, Universitas Padjadjaran Bandung, Indonesia.

The research used an experimental designed of Randomized Block Design (RBD) with factorial pattern, consisted of two factors: steel slag and rice husk bokashi each consisted of four levels/dosages. The dosages were based on the soil weight percentage, either steel slag (s_0, s_1, s_2, s_3) or rice husk bokashi (b_0, b_1, b_2, b_3) consisted of 0, 2.5, 5.0 and 7.5% of soil weight percentage respectively. The combined treatments resulted in 16 combinations and repeated three times made 48 experimental pots (polybags). Before and after incubation, the soils were analyzed for P-retention and available P.

The soils used for every treatment was 10 kg. The soils were mixed with the treatments according to the dosages evenly and placed in the polybags. The polybags were then watered to the field capacity, tied to prevent evaporation, arranged in the field according to the Randomized Block Designed in the distance of 60 x 50 cm, and incubated for four months. After incubation period the soil samples were taken to be analyzed.

Every polybag were treated with basic fertilizers like nitrogen (350 kg Urea Ha^{-1}), phosphorus(100 kg SP36 Ha^{-1}) and kalium (75 kg KCl Ha^{-1}) referred to Badan Penelitian dan Pengembangan Pertanian (2020). The sweet corn seed was planted directly to the polybag after incubation. The parameter of corn growth was observed every two week. The sweet corn was harvested at 62 days. After harvested, the soils in every polybag were sampled to be analyzed.

Soil chemical and physical analyzing before and after incubation and after harcesting refer to Van Reewijk (2002) covered P-retention, available P, organic carbon, CEC, base saturation, Al and Fe with acid ammonium oxalate. The analyses of rice husk bokashi before treatment covered the pH, CEC, organic carbon, total nitrogen which also referred Van Reeuwijk (2002). and bulk density. The analysing of steel slag prior to treatments were done in the Laboratory of Mineral and Coal Technology, Bandung covered the analyses of SiO_2, CaO, MgO, P_2O_5, FeO, water content and bulk density.

3. RESULTS AND DISCUSSION

3.1 The characteristics of soil, steel slag and rice husk bokashi prior to the treatmens

The chemical and physical characterisics of the soils (Table 1) showed some noted characteristics of Andisols. Related to keys to be classified as Andisols, the andic soil properties have to be fulfilled, The value of 4.43% of organic carbon, 0.90 g cm^{-3} of bulk density, 88.86% of P-retention and 5.0 of Al + ½ Fe with acid ammonium oxalate were satisfied to meet the requirements of andic soil properties since it must be 25% or less for organic carbon, 0.90 g cm^{-3} or less for bulk density, 85% or more for P-retention and 2% or more for Al + ½ Fe with acid ammonium oxalate (Soil Survey Staff, 2014). The low (9.41 ppm) of available P following the high P-retention (88.86%) was one of the problems ini Andisols that would like to be solved in this research.

Table 1. Physical and chemical characteristic of the soil prior to the treatments,

No	Parameters	Unit	Value	Criteria*)
1.	Organic Carbon	%	4.43	High
2.	Bulk density	g cm^{-3}	0.90	low
3.	P-retention	%	88.86	high
4.	Al + ½ Fe (acid amonium oxalate)	%	5.00	high
5.	Available P	mg kg^{-1}	9.41	low
7.	pH H_2O	-	5.49	acid
7.	Cation Exchange Capacity (CEC)	cmol kg^{-1}	22.62	medium
8.	Base Saturation	%	30.35	medium

The characteristics of steel slag and rice husk bokashi (Table 2) informs that silicate was high (12.5%). Other oxides contributed in the ingridient were CaO (42%), MgO (6%), P_2O_5 (0.5%) and FeO (0.81%). The silicate in steel slag was expected to release some silicate anions (SiO_4^{-4}). These anions were looked forward to to replace the ion of $H_2PO_4^{-1}$ that retained in the soils. Calsium and magnesium in steel slag were quite high (42% CaO and 6% MgO). Calsium oxide and magnesium oxide in the soil can react to release some OH^- anions and will increase soil pH, besides contribute Ca and Mg as essential nutrient.

Analyses of rice husk bokashi showed that the characteristics can support the soil improvement. The pH was high 7.47, and when be applied to the soil will stabilize the soil pH. Another important characteristic was the low C/N ratio (17.96 or less than 20), indicated that it can be used as ameliorant and expected can release some anions for replacing retained phosphate ions in the soils.

Table 2. Analyses of steel slag and rice husk bokashi prior of treatments

Steel slag			
No.	Parameters	Unit	Value
1.	SiO_2	%	12.50
2.	CaO	%	42.00
3.	MgO	%	6.00
4.	P_2O_5	%	0.50
5.	FeO	%	0.81
6.	Water content	%	1.00
8.	Bulk density	g cm^{-3}	1.70
Rice husk bokashi			
No.	Parameters	Unit	Value
1.	pH H_2O	-	7.47
2.	CEC	cmol kg^{-1}	50.01
3.	Organic carbon	%	24.64
4.	Total nitrogen	%	1.37
5.	C/N	-	17.96
6.	Bulk density	g cm^{-3}	0,3

3. 2 P-retention

Steel slag and rice husk bokashi did not interact in decreasing the P-retention but rice husk bokashi individually decreased the P retention from 92.33% (wihout rice husk bokashi) to 84.58% (7.5% rice husk bokashi), as can be seen in Table 3. During the incubation periode a certain amount of negative charge from rice husk bokashi blocked the positive charge of volcanic ash soil, resulted in the decreasing of P retention. Anion from organic material can release the P and decrease the P retention (Boniao, 2000). In this research, the application of 2.5 to 7.5% rice husk bokashi invidually, reduced P-retention.

Table 2. Individual Effect of Rice Husk Bokashi on P Retention After Incubation

Treatment	P-retention (%)
b_0	92.33 a
b_1	93.33 a
b_2	92.18 a
b_3	84.58 b

Notes: Numbers followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 5% level.

Humic acid and silicates are expected to decrease due to the ability to fill the P retention tread the purpose of this experiment. The results showed that P retention by allophane generally very high at > 90%. The high P retenstion by allophane is an amorphous mineral component of Andisols caused by the high content of Fe and Al amorphous allophane (Bohn et al., 1979), large specific surface (Uehara and Gillman, 1981) and pH. Masduqi (2004) suggested that the acidic pH of the soil causes the positively charged due to the influx of H^+ ions in the octahedral layer of $Al(OH)_3$ and form hydrogen bonds so that the surface of allophane particles become positively charged and can bind the negatively charged phosphate ions. Van Ranst (1994) wrote that the reaction produces hydroxyl ions which can lead to increased pH:

$$SiO_4^{-4} + H_2O \rightarrow SiO_3(OH)^{-3} + OH^-$$
$$SiO_3(OH)^{-3} + H_2O \rightarrow SiO_2(OH)_2^{-2} + OH^-$$
$$SiO_2(OH)_2^{-2} + H_2O \rightarrow SiO(OH)_3^- + OH^-$$
$$SiO(OH)_3^- + H_2O \rightarrow SiO(OH)_4 + OH^-$$

When the phosphate sorption, anion coordination occurs with surface metal ions. H_2O molecules and OH ions that migrate to the metal ion is replaced by a phosphate ion $H_2PO_4^-$. OH^- ion replacement by phosphate ions result in a reduction of positive charge.

3.2 Available P

The experimental results showed that steel slag and rice husk bokashi did not interact on available P after incubation. However, rice husk bokashi individually increased available P as can be seen in Table 4.

Table 4. Individual Effect of Rice Husk Bokashi on Available P After Incubation

Treatment	Available P (ppm P)
b_0	102.17 a
b_1	79.21 a
b_2	129.96 a
b_3	254.75 b

Remarks: Figures followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 5% level

Organic matter is one of the P sources, as organic matter mineralizes and produces most of nutrients including P (Soepardi, 1983). Rice husk bokashi as organic matter during the decomposition contributes some phosphates to the soils that increase available P. Basically, phosphates in the soil are in organic and inorganic form. In case of rice husk bokashi, organic form of rice husk bokashi decompose to release anorganic form of phosphate ions that available for plant. Further, the availability of inorganic P depends on several determining factors like soil pH, available Fe, Al, and Mn, available Ca, the rate of decomposition, and the activity of microorganisms in the soil.

3.3 Corn Biomass

The interesting phenomenon found in corn biomas. Even thought steel slag and rice husk bokashi did not interact in decreasing P-rentention and increasing available P due to nutrient balance as mention in Roy et al. (2003). These combination interacted in increasing corn biomass as shown in Table 4

Table 4. The effect of combination of steel slag and rice husk bokashi on corn biomass (g)

Steel Slag	Rice Husk Bokashi			
	b_0 (0%)	b_1 (2,5%)	b_2 (5,0%)	b_3 (7,5%)
s_0 (0%)	149.41 (a) B	92.37 (a) A	131.52 (a) A	130.11 (a) A
s_1 (2,5%)	65.43 (a) A	131.12 (a) A	108.36 (a) A	170.73 (b) B
s_2 (5,0%)	128.94 (a) A	129.46 (a) A	144.84 (a) A	217.68 (b) B
s_3 (7,5%)	170.54 (b) B	106.29 (a) A	170.76 (b) B	137.09 (a) A

Note: The letters in parentheses are read vertically direction, the letters without parentheses are read horizontally. Same lettters indicates no difference of the value between the treatments with Duncan Multiple Range Test 5%

Steel slag and rice husk bokashi interacted in increasing corn biomass, where the combination of 2.5% and 5.0% steel slag with 7.5% rice husk bokashi resulted in biomass of 170.73 g and 217.68 g. Steel slag in soil reaction release some silicate and OH anions replaced the retained phosphate to be available for corn. Some OH anions also can increase soil pH that optimize soil reaction and nutrient absorption of corn. The decomposition of rice husk bokashi also contribute some OH anions and nutrients that support corn growth. This combination interacted in increasing corn biomass in the level of 2.5% and 5% of steel slag and 7.5% of rice husk bokashi.

4. CONCLUSION

1. Slag steel and rice husk bokashi did not interact in decreasing P-retention and increasing available P in Andisols, but 7.5% of rice husk bokashi individually decreased P-retention to 84.58% and increased available P to 254.75 ppm P
2. Slag steel and rice husk bokashi interacted in increasing corn biomass in Andisols, where the combination of 2.5% and 5.0% steel slag with 7.5% rice husk bokashi resulted in corn biomass of 170.73 g and 217.68 g

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