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EFFECTS OF STEEL SLAG AND BOKASHI OF RICE HUSK ON PHYSICAL PROPERTIES OF ANDISOLS

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ABSTRACT

Andisols are considered as productive soils, but their P-retention have to be reduced to increase the available P. This research is concerning the remediation of Andisols using steel slag and bokashi of rice husk to overcome the P problem and to investigate their influence on soil physical aspects. The treatments were arranged in Randomized Block Designed in factorial pattern with two factors: steel slag and bokashi of rice husk, consisted of four level: 0, 2.5, 5.0 and 7.5 % of soil weight (w/w). The treatments were repeated twice, brought a combination of 4 x 4 x 2. The soils with each treatment were mixed thoroughly, filled into the polybags, watered to the field capacity, closed tightly, incubated for four months, and sampled for chemical and physical analyses. The parameters were P-retention, bulk density, permeability and aggregate stability. The result showed that steel slag and bokashi of rice husk were interacted in decreasing P-retention. These combinations had no effect on soil physical characteristics which meant that the treatments did not aggravate the bulk density, soil permeability and aggregate stability. The remediation of Andisol with steel slag and bokashi of rice husk decreased the P-retention, and kept the good aspects of soil physical characteristics.

Key words: P-retention, Bulk density, Permeability, Aggregate stability

PENGARUH TERAK BAJA DAN BOKASHI SEKAM PADI TERHADAP SIFAT FISIKA TANAH PADA ANDISOL

ABSTRAK

Andisol merupakan salah satu tanah yang produktif, akan tetapi mempunyai masalah karena retensi P yang tinggi yang harus dikurangi agar ketersediaan P dapat meningkat. Penelitian ini adalah mengenai remediasi Andisol dengan terak baja dan bokashi sekam padi untuk mengatasi masalah retensi P dan mengetahui pengaruhnya terhadap sifat fisika tanah. Rancangan perlakuan berupa Rancangan Acak Kelompok pola faktorial dengan dua faktor yaitu terak baja dan bokashi sekam padi yang terdiri dari empat taraf: 0 , 2,5, 5,0 dan 7,5 % dari berat tanah (berat/berat). Perlakuan diulang dua kali, dengan total perlakuan 4 x 4 x 2. Tanah dengan masing-masing perlakuan dicampur secara merata, diisi ke dalam polibeg, disiram sampai kapasitas lapang, ditutup rapat, dan diinkubasi selama empat bulan untuk kemudian diambil sampel kimia dan fisika tanah. Parameter yang diukur adalah retensi P, bobot isi, permiabilitas dan stabilitas agregat. Hasil penelitian menunjukkan bahwa terak baja dan bokashi sekam padi berinteraksi dalam menurunkan retensi P, tetapi tidak berinteraksi dalam memadatkan bobot isi, menurunkan permiabilitas dan menurunkan stabilitas agregat. Remediasi Andisol dengan terak baja dan bokashi sekam padi menurunkan retensi P dan tetap menjaga aspek-aspek baik dari sifat fisika tanah.

Kata kunci : Retensi P, Bobot isi, Permeabilitas, Stabilitas agregat

INTRODUCTION

Soils classified as Andisols if fulfills the requirement of andic soil properties: the organic carbon is less than 25%, bulk density is 0.9 gcm^{-3} or less, phosphate retention / P-retention is 85% or more, and the sum of Alumininum (Al) and ½ Ferum (Fe) with acid ammonium oxalate is 2% or more (Soil Survey Staff, 1990; Soil Survey Staff, 2010).

Among those properties, the P-retention that 85% or more is a serious problem. Phosphorus availablity is therefore very limited. Fertilization of P will never be effective due to the P fertilizer will immediately be retained by soil. Egawa (1984) informed that only ten percent of P fertilizer will be available for plants.

Andisols actually is one of the most productive soil in the world, due to its high potentiality for serving nutrients from rapid weathering of pyroclastic materials. Further, it has an excellent soil physical characteristics like low bulk density range from 0.4 – 0.9 g cm^{-3} and high porosity , high water holding capacity in soil pores which can hold hygroscopic water of 35-36%, capillary water of 21-27%, gravitational water of 36-40% and high permeability of 10-3to 10-4 cm sec^{-1} (Bielders *et al*., 1990).

However in contrast to some distinguish chemical and physical characteristics, Andisols have high phosphate retention which considered as a factor to impoverish this soil (Nanzyo *et al.,* 1993). Meanwhile, Andisols have high human carrying capacity in serving food, fiber and forage, therefore should be preserved and rescued. Overcome the problem of P-retention to maintain its productivities properly is one of the the goal in improving the productivity of Andisols, that can be done by adding the silicate and organic matter. Steel slag and bokashi of husk can be used as silicate and organic matter in releasing the P retention in Andisols.

The main purpose of application steel slag and bokashi of husk is to maintain the soil chemical characteristics like reducing P-retention and increasing available P. Meanwhile, the soil physical characteristics like bulk density, permeability, and aggregate stability are somewhat shadowed from the effect of those applications. There was not much research considering the effect of chemical application to the soil physical characteristics. Whereas, those physical characteristics are the excellence hallmark of Andisols that must be protected due to allow the optimization of roots penetration and aerase condition. Application of steel slag is worried not only improve the soil chemical characteristics in one side, but aggravate the soil physical characteristics in another side. Steel slag has a high bulk density (1.7 g cm^{-3}) meanwhile Andisols has a low bulk density (≤ 0.9 g cm^{-3}). Applying the steel slag to Andisols is considered to tamp the soil and increase the bulk density, and decreasing the permeability and aggregate stability.

This paper is to discuss the soil chemical properties like P-retention and soil physical properties of Andisols like bulk density, permeability and aggregate stability after be treated with steel slag (as silicate) and bokashi (as organic matter) .

METHODOLOGY

The soils for this research were collected from the agricultural field of Balai Penelitian Tanaman Sayuran (Balitsa) in Lembang, West Java. The experimental soil samples were acquired from several points in the research land on the depth of 0-20 cm. The soil were compositely mixed before be prepared for the treatments. Undisturbed soil samples taken with ring samples were used for measuring the bulk density and permeability.

The experimental research was conducted in laboratory with the relative humidity of 80% and average temperature of 26^0 C. Before treatments, the soils were crushed to pass 2 mm sieve and measured its water content. Randomized designed in factorial with two factors were used in the experimental polybags. The first factor was steel slag and the second factor was bokashi of husk with four levels: 0, 2.5, 5.0 and 7.5% of soil on weight/weight (w/w) basis respectively, by considering the bulk density and water content. Soil used was 10 kg per polybag. The treatments were repeated two times, gave a total 4x4x2 = 32 polybags. The combination of the treatments of this research is shown in Table 1, where s is stand for steel slag, and b is stand for bokashi of husk. The numeric of 0, 1, 2, and 3 represents the percentage of dossage treatments of 0, 2.5, 5.0, and 7.5% of weight percentage (w/w) to the soil respectively.

Table1. Combination of the treatments of steel slag and bokashi of husk

Treatments		Steel slag (in weight percentage of soil)			
		s_0	**s_1**	**s_2**	**s_3**
Bokashi of husk (in weight oercentage of soil)	b_0	s_0b_0	s_1b_0	s_2b_0	s_3b_0
	b_1	s_0b_1	s_1b_1	s_2b_1	s_3b_1
	b_2	s_0b_2	s_1b_2	s_2b_2	s_3b_2
	b_3	s_0b_3	s_1b_3	s_2b_3	s_3b_3

Steel slag was obtained from PT. Krakatau Steel Indonesia and have been grinded by PT. Purna Baja Heckett to pass the diameter sieve of 50 mesh. This grinded steel slag were crushed again in the Laboratorium Teknologi Mineral dan Batubara (Tekmira) Bandung to the size of 200 mesh. Bokashi of husk were made by fermented the husk by the addition the microorganisms for 4 weeks.

The soils were mixed thoroughly with steel slag and bokashi of husk according to the treatments. The control soils without treatments were also mixed themselves in order to reduce experimental errors. The mixtures of soil with defined treatments were then filled into 32 polybags (diameters of 60 cm to a depth of 60 cm), and added the water to field capacity. The polybags were tighted to protect the soil moisture. The soils were incubated for four months. Water was added if necessary every three days to keep the soils in their field capacity.

The soil analyses before treatments to the soil include pH H_2O and KCl with glass electrode (Van Reeuwijk, 1992), P-retention (Blakemore et al., 1987), available P (Van Reeuwijk, 1992), bulk density (Blake and Hartge, 1986), Al + ½ Fe with acid ammonium oxalate (Van Reeuwijk, 1992), permeability (Klute and Dirksen, 1986), and aggregate stability (Kemper and Rosenau, 1986). After treatments and incubation, every soils in every treatments were analysed for P-retention (Blakemore et al., 1987), bulk density, permeability, and aggregate stability. The steel slag was analysed for silicate, carbonate and phosphate. The bokashi was analysed for the pH, organic carbon, total nitrogen, C/N ratio.

Analysis of variance (ANOVA) was performed by SPSS Statistical Package (SPSS 13.0, SPSS Science, Chicago, IL). The Duncan's New Multiple Range Test was used for testing the mean differences.

RESULTS AND DISCUSSION

1. Analyses of Soil, Steel Slag and Bokashi of Husk Prior to the Treatments

The soil chemical analyses of the soils prior to treatments is presented in Table 2. The data indicated that the soil pH H_2O is slightly acid (5.49). The acidity of the soil was the reflection of andesitic of parent rock and parent material (Alzwar et al, 1976). The value of pH KCl was 4.97 and the delta pH (pH KCl – pH KCl) is - 0.62 indicated that this soil has the potentiality as a variable charge soil. The organic carbon is high (4.43%), P-retention is very high 90.96%), the bulk density is low (0.87 g cm^{-3}), Al plus ½ Fe with acid ammonium oxalate is high (5.00%). The whole value of organic carbon, P-retention, bulk density and Al + ½ Fe are fulfilled the requirements of andic soil properties comprise of the organic carbon must be less than 20%, P-retention must be more than 85%, the bulk density must be lower than 0.9 g cm-3, Al plus ½ Fe with acid ammonium oxalate must be higher than 2% (Soil Survey Staff, 1990; Soil Survey Staff, 2010).

Table 2. Analyses of soil chemical and physical characteristics prior of treatments

No	Parameters	Unit	Value	Criteria
1.	pH (H_2O)	-	5.49	Acid
2.	pH (KCl 1 N)	-	4.87	-
3.	Organic carbon	%	4.43	High
4.	P-retention	%	88.86	High
5.	Bulk density	g cm^{-3}	0.87	Low
6.	Al + ½ Fe	%	5.00	High
7.	Permeability	cm h^{-1}	3.18	Moderate to slow
8.	Aggregat stability	-	6.84	Low

The characteristics of steel slag and bokashi of husk is presented in Table 3. The steel slag used indicate that the content of silicate is high (12.5%). During incubation periode, the silicate was expected to release the anion to block the positive charge of Andisols and then release the P-retention to have the available P. Ottinger (2013) inform that silicate can function as anion in releasing P-retention. The concentration of Ca was very high (42.00%) which can function as lime to increase the pH and also help in releasing P-retention. Meanwhile the analyse of bokashi of husk indicated that the pH was high (7.47), expected in increasing soil pH. The C/N ratio was 17.95 indicated it can function as organic matter in serving the organic anion to block the positive charge of Andisol to release the P retention.

Table 3. Analyses of steel slag and bokashi of husk 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
Bokashi of husk			
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.	Water content	%	41.55
7.	Bulk density	g cm^{-3}	0,3

2. Influence of Steel Slag and Bokashi of Husk to P-retention and Soil Physical Characteristics

a. P-retention

Application of steel slag and bokashi of husk interacted in influencing the P-retention as presented in Table 4. Table 4 informs the influence of steel slag and bokashi of husk on P retention of Andisols.

Tabel 4. The influence of steel slag and bokashi of husk on P-retention of Andisols

Bokashi of Husk	Steel Slag			
	0%	2.5%	5%	7.5%
	P-retention (%)			
0%	90.96 (b) C	86.08 (ab) B	86.60 (ab) B	85.10 (b) AB
2.5%	92.16 (b) C	86.85 (b) B	84.29 (ab) A	86.10 (b) B
5%	86.83 (a) B	85.19 (a) AB	85.99 (bc) B	84.05 (ab) A
7.5%	95.40 (c) D	92.16 (c) C	87.36 (c) B	**83.09 (a) A**

Note: Numerics followed by the same letters were non significant on 5 % Duncan's New Multiple Range Test. Letters with brackets are red vertically and letters without brackets are red horizontally.

Application of steel slag and bokashi of husk had the important effect on decreasing the P-retention. During the incubation periode a certain amount of negative charge from silicate and bokashi of husk blocked the positive charge Andisols made the P retention decreased. Hartono (2008) informed that silicate from calsium silicate can decreased significantly the P bonding. Beck et al (1999) showed that anion from organic material can release the P-retention. In this research, the application of 7.5% steel slag combined with 7.5% bokashi of husk gave the best reduction of P-retention to 83.09%. However, some other treatments like combination of 5% steel slag with 2.5% bokashi of husk also gave the significant reduction to 84.29%.

The treatments of steel slag and bokashi of husk decreased the P-retention as expected by this research. However, besides the chemical characteristic, the physical characteristics were the important aspects that have to be investigated in this research. The influence of these treatments to some physical characteristics like bulk density, permeability and aggregate stability.

b. Bulk Density

Application of steel slag and bokashi of husk did not interact in influencing the bulk density. The individual effect was then further investigated to know whether the steel slag and bokashi of husk individually influenced the bulk density. The result showed that the steel slag has no significant effect on bulk density of the soil. On the contrary, bokashi of husk had the significant effect to the soil bulk density as presented in Table 5.

Table 5. The influence of bokash of husk on soil bulk density

Treatments of bokashi of husk (b)	Bulk density ($g\ cm^{-3}$)
b_0 (without bokashi of husk)	0.87 a
b_1 (2.5% bokashi of husk)	0.60 b
b_2 (5% bokashi of husk)	0.53 c
b_3 (7.5% bokashi of husk)	0. 48 c

Note: Numerical followed by the same letters were non significant on 5 % Duncan's New Multiple Range Test.

The analyses of bulk density informed that steel slag and bokashi of husk has no effect on bulk density. The doubtfulness of the steel slag that have high bulk density (1.7 g cm-3) much higher than soil bulk density (0.9 g cm-3) will increase the bulk density of the media was therefore unproven. It did not increase the bulk density neither in combination with the bokashi of husk nor in combination with bokashi of husk (individual treatmens). In the other side, bokashi of husk as an individual treatment exactly decreased the bulk density from 0.87 g cm-3 to 0.6 g cm-3 (treatment of 2.5% bokashi of husk) to 0.53 and 0 .48 g cm-3 (treatments of 5% and 7.5% bokashi of husk). This result was not appropriate with Eluozo (2013), which found that the addition of organic matter did not significantly influence the bulk density. In this case, the dosage of organic matter used were different. Eluozo (2013) used a low dosage, meanwhile organic matter (bokashi of husk) used in this research were sufficient to decrease the bulk density. In the other hand, Perie and Quimet (2007) found the similar result with this research, where the increasing of organic matter will decrease the bulk density.

These results informed us that the steel slag as an individual treatments or as the combination with the bokashi of husk will not increase the low bulk density of Andisols. It means that the excellence physical property of low bulk density will not be disturbed by the application of steel slag and bokashi of husk. The main purpose of these application in decreasing the P-retention was therefore can be continued.

c. Permeability

Application of steel slag and bokashi of husk did not interact in influencing the soil permeability. The individual effect was then further investigated to know whether the steel slag and bokashi of husk individually influenced the permeability. The result showed that the steel slag had no significant effect on permeability. On the contrary, bokashi of husk had the significant effect to the permeability as presented in Table 6.

Table 6. The influence of bokash of husk on soil permeability

Treatments of bokashi of husk (b)	Permeability ($cm\ hour^{-1}$)
b_0 (without bokashi of husk)	3.18 a
b_1 (2.5% bokashi of husk)	6.35 ab
b_2 (5% bokashi of husk)	6.51 ab
b_3 (7.5% bokashi of husk)	10.11 c

Note: Numerical followed by the same letters were non significant on 5 % Duncan's New Multiple Range Test.

The analyses of permeability showed that steel slag and bokashi of husk has no effect on permeability. Steel slag individually or combined with bokashi of husk did not decrease the soil permeability. The positive point was found in the treatments of bokashi of husk, which significantly increased the permeability from 3.18 cm $hour^{-1}$ (moderate-slow) to 6.35 and 6.51 cm $hour^{-1}$ (moderate) with the treatments of 2.5 and 5% bokashi of husk respectively, up to 10.11 cm $hour^{-1}$ (moderate) with the treatment of 7.5% bokashi of husk. Bouajila and Sanaa (2011) informed the same result with this research where the increasing of organic matter will increase the permeability.

These results informed us that the treatments of steel slag and bokashi of husk did not decrease the soil permeability. The treatments of bokashi of husk individually even increased the permeability from moderate-slow to moderate which increased the quality of soil in the physical characteristics point of view.

d. Aggregate Stability

Application of steel slag and bokashi of husk did not interact in influencing the aggregate stability. The individual effect was then further investigated to know whether the steel slag and bokashi of husk individually influenced the aggregate stability. The result showed that the steel slag has no significant effect on aggregate stability. On the contrary, bokashi of husk had the significant effect to the aggregate stability as presented in Table 7.

Table 7. The influence of bokash of husk on aggregate stability

Treatments of bokashi of husk (b)	Aggregate Stability
b_0 (without bokashi of husk)	6.84 a
b_1 (2.5% bokashi of husk)	3.41 b
b_2 (5% bokashi of husk)	2.33 c
b_3 (7.5% bokashi of husk)	2.08 c

Note: Numerical followed by the same letters were non significant on 5 % Duncan's New Multiple Range Test.

Table 7 showed that the the increasing dossage of bokashi of husk decreased the numerical of aggregate stability. It meant that the aggregate will be more stable. The increasing of the dossage of bokashi of husk increased the aggregate stability.

The whole analyses informed us that the application of steel slag and bokashi of husk as the ameliorant in decreasing of the P-retention, had the capacity in decreasing P. The combination of 7.5% of steel slag and 7.5% of bokashi of husk gave the best result in decreasing P retention. The supposition about these treatments will decrease the physical soil characteristics were unproven due to they had no influenced on bulk density, permeability, and aggregate stabiliy. The treatments did not increase bulk density, did not decrease the permeability and aggregate stability as well. The steel slag as individual treatments also had no bad influence to those soil physical charac-teristics. In the other hands, the bokashi of husk as the individual treatments had the good influence to soil physical haracteristics due to can decreasing the bulk density, increasing the permeability and increasing the aggregate stability.

CONCLUSIONS

The research concluded:

1. Steel slag and bokashi of husk interacted in reducing the P-retention.
2. Steel slag and bokashi of husk did not interact in tamping bulk density,

decreasing permeability and aggregate stability.
Steel slag independently had no effect to soil physical parameters, while bokashi of husk independently decreased bulk density, increase permeability and aggregate stability.

3. The remediation of Andisol with steel slag and bokashi of husk decreased the P-retention, and kept the good aspects of soil physical characteristics.

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