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MICRO PARTICLE STEEL SLAG AND ITS EFFECT ON SOIL CHEMICAL CHARACTERISTICS OF ULTISOLS

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ABSTRACT

Steel slag is a by-product in the process of refining iron. This by-product content several nutrients compound that useful for agriculture. This study aimed to observe the influence of steel slag (powdered into micro paricle sized in 1.7 µm) in improving some soil chemical characteristics of Ultisols. The method used was the experimental of Completely Randomized Design consisted of 11 treatments of several dosages of micro particle of steel slag (in weight percentages w/w with soils): 1%, 2%. 3%. 4%, 5%. 6%, 7% 8%. 9%, and 2 controls. One control was the treatment without steel slag. Another control was 5% steel slag in 200 mesh sized or 78 µm (size of applied lime). Overal total treatments were 11 and repeated three times, gave the total of 33 treatments. The soils used were 1kg, mixed with the steel slag according to the dosages. They were put into the polybag watered to field capacity and incubated for two months. After two months the soils were analysed for pH, P-fixation and available P. The result showed that the steel slag increased the pH, decreased the P-fixation and increased available P.

Keywords: pH, P-fixation, Available P, Completely Randomized Design.

1. INTRODUCTION

Steel slag is a by-product of the iron refining process in the steel industry. The refining process produces pure steel, with steel slag as the by-product. As a by-product, steel slag is waste, conversely it still can be utilized for various uses, such as the cement industries. road constructions, bridges and buildings [1]. Steel slag also can be used for agriculture purposes, due to containing Ca, Mg and Si, makes this material has the potentiality to be used as fertilizer and/or ameliorant. The presence of these elements in steel slag comes from the iron refining process which requires the addition of various naterials. Steel is then produced from iron ore (iron oxide) which processed in heating furnace [2]. The materials introduced into heating furnace are iron ore itself, carbon, lime-calcium oxide, calcium carbonate, calcium magnesium carbonate. The reation causes the waste materials from ores (among them silica and other material) to be converted into slag (silicate). These processes and reactions occur continuously. Iron ore is refined into steel slag, and steel slag is produced as a by-product. Some content in steel slag like Ca and Mg are the potential elements in increasing pH due to in soil reaction they can realise some OH^{-1} This OH^{-1} will contribute in increasing soil pH. Ion OH^{-1} also will react with Al^{+3} forming a solid form of $Al(OH)_3$.

Silicates are the compound that consist of both silicon and oxygen. Its general formula is $(SiO_{4-x})_n^{-4}$ [3]. In the soils, the negative ions (anions) or negative charge of silicates can react to the positive charge of several compounds result in stable complex Silicate in steel slag function

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as anion that react with Al forming aluminum compound of $Al(OH)_3$ that unhazardous in Ultisols.

The steel slag produced in chunk form, which must be processed into fine sizes in order to applied for agricultural uses. The finer size leads to a larger surface area, allows the reactions faster [4]. Micro-sized particles are expected to react faster than mesh-sized particles. This particle is expected to release the nutrient and ameliorant contained in steel slag to improve soil characterics including increase the pH value, reducing or releasing P-fixation and increasing available P which is often a probem in various soils including Ultisols.

Ultisols is one of the most widely soils order in Indonesia. It is estimated around 48 miljoen hectare or almost 25% of Indonesia's total area, distributed in almos all Indonesian islands. Its wide distribution makes Ultisols very potential in the development of dryland agriculture in Indonesia [5].

Most of the Ultisols develops from acidic parent materials, result in acid soils with low pH. Cation exchange capacity (CEC), basic cations, base saturation (BS) and organic matter content are also low. However, some acid cations like Al dan Fe are high, which tend to fix phosporus, makes the P-fixation is high and available P is high [6].

Efforts that can be made to improve Ultisols characteristics are by applying the ameliorants that can increase the soil pH, and reduce the level of Al and Fe. This improvement further can decrease P-fixation and increase available P. Calsium in steel slag can be contribute as lime in increasing soil pH. Silicate in steel slag act as anion and replace phosphate that fixed by aluminum. It will decrease P-fixation and increase available P.

Research related to observe the influence of micro particle of steel slag in improve chemical characteristics of Ultisols is steel rare to be published. This study was done to compile and report the influence of steel slag micro particle on several soil chemical characteristics of Ultisols

2. METHODOLOGY

The research was done in experimental design of Completely Randomized Design. Ultisols was retrieved from Citatah District Bandung Barat Regency of West Java Province, Indonesia. The soils was taken from the upper 30 cm in several spot and mixed homogenously. The steel slag was obtained from PT Krakatau Steel Indonesia. The steel slag was powdered and analysed in the Laboratory of Center for Research and Development of Mineral and Coal Technology. The incubation process and the analyses of soils before and after incubation were done in the Laboratory of Soil Physics and Soil Fertility and Plant Nutrition of Faculty of Agriculture Universitas Padjadjaran. The analyses of pH used pH meter, P-fixation and available P used Flamephotometer, following [7].

Experimental design was Completely Randomized Design with evelent dosages treatment as follow:

A = Control (without steel slag)
B = 1% micro particle steel slag sized 1,7 µm
C = 2% micro particle steel slag sized 1,7 µm
D = 3% micro particle steel slag sized 1,7 µm
E = 4% micro particle steel slag sized 1,7 µm
F = 5% micro particle steel slag sized 1,7 µm

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G = 6% micro particle steel slag sized 1,7 µm
H = 7% micro particle steel slag sized 1,7 µm
I = 8% micro particle steel slag sized 1,7 µm
J = 9% micro particle steel slag sized 1,7 µm
K = 5 % of steel slag 200 mesh sized

The differentiation between treatments were analysed using Duncan Multiple Range Test (DNMRT).

The soils used were 1 kg, mixed homogenously with the steel slag according to the dosages. They were then put into the polybag, watered to field capacity and incubated for two months. After two months the soils were analysed to observe the change of soil characteristics, in this case: pH, P-fixation and available P.

3.RESULT AND DISCUSSION

3.1 Soils and steel slag characteristics prior to incubation

The soils and steel slag were analysed before treatment, and the result is presentented in Table 1 and 2. Table 1 informed that the parameters observed was unfavorable for plant. The pH was acid, the P-fixation was very high and available P was low. In the other hand total P was high. There was the indication that available P can be increase due to P reserve (total P) was high enough, which can be released into available P if soil reaction supported.

Table 1. Chemical characteristic of the soil before treatments

No	Parameters	Unit	Value	Criteria*)
1.	pH H_2O	-	5,10	acid
2.	P-fixation	%	76.44	very high
3.	Available	$mg.kg^{-1}$	6.92	low
4.	Total P	%	25.23	high
5.	Organic Carbon	%	1,7	Low
6.	Total N	%	0,12%	low
7.	CEC	Cmol. Kg^{-1}	12,90	low
8.	Ca	Cmol. Kg^{-1}	0.80	low
9.	Mg	Cmol. Kg^{-1}	0,52	Low
10.	K	Cmol. Kg^{-1}	0,24	Low
11.	Na	Cmol. Kg^{-1}	0,20	low
12	Base Saturation	%	13,56%	Low
13	Al-dd 1,33	Cmol. Kg^{-1}	1.33	high

Note:
*) The criteria was according to [8]

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Table 2. Analyses of steel slag before treatments

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	%	0.00
8.	Bulk density	g cm^{-3}	1.70

Tabel 2 informed that the silicate content is high (12.5%). During incubation periode, the silicate was expected to release the silicate anion to replace phosphate anion that fixed by aluminum, adding some available P to the soil [9] inform that silicate can function as anion. This anion can function in releasing P-fixation. The concentration of Ca was very high (42.00%) which can function as lime to increase the pH and also help in releasing P-fixation, and also increase available P [10].

3.2. Soil pH

The result of soil pH is presented in Table 3. It was shown that all of the treatments significantly different with the control (without steel slag). The increasing pH was seen starting from the dosage of 1% micro particle steel slag, and increased with the increasing dosages. The highest pH reached at the highest dosage of 9% steel slag. Treatment with 200 mesh sized also increased the pH value, significantly different with control, and not signicantly different with the treatments of 2 to 9% of micro particle sized dosages.

Table 3. Soil pH value after 2 month incubated with several dosages steel slag

Treatments	Soil pH
A= Control (without steel slag)	5,10 a
B= 1% micro particle steel slag sized 1,7 µm	6,85 b
C= 2% micro particle steel slag sized 1,7 µm	7,23 bc
D= 3% micro particle steel slag sized 1,7 µm	7,47 cd
E= 4% micro particle steel slag sized 1,7 µm	7,41cd
F= 5% micro particle steel slag sized 1,7 µm	7,43 cd
G= 6% micro particle steel slag sized 1,7 µm	7,63 cde
H= 7% micro particle steel slag sized 1,7 µm	7,79 de
I= 8% micro particle steel slag sized 1,7 µm	7,83 de
J = 9% micro particle steel slag sized 1,7 µm	7,96 e
K= 5 % of steel slag 200 mesh sized	7,63 cde

Note: Same lettters indicates no difference of the value between the treatments with Duncan Multiple Range Test 5%

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The increasing pH showed that Ca and Mg content in steel slag function as lime in the soils. The reaction of Ca and Mg soils in increasing pH are the series of reaction, where several OH^{-1} ions are released [11]. The ions contributed to the increasing of soil pH value.

The micro particle sized encouraged the acceleration of the reaction, where the finer the particle the fast the reaction happened. Finer particle with higher surface area contributed in releasing higher OH^{-1} ions to increase pH.

3.3 P-fixation

The result of P-fixation after incubation is presented in Table 4. The P-fixation prior to the treatment was 76.44% (Table 1). Micro particle steel slag was expected can deacrease the fixation. After two months incubation, the change of of fixation can be seen in the Table 4. The data in Table 4 showed that the treatments with several dosages of micro particle steel slag not significantly decrased the P-fixation. However, the treatments of 2 and 3% of micro particle steel slag showed the lowest P-retention eventhoght they were not significantly decrease with control.

Table 4. P-retention after 2 months incubated with several dosages micro particle steel slag

Treatments	P-retenton (%)
A= Control (without steel slag)	74,95 ab
B= 1% micro particle steel slag sized 1,7 µm	74,98 ab
C= 2% micro particle steel slag sized 1,7 µm	71,54 a
D= 3% micro particle steel slag sized 1,7 µm	71,38 a
E= 4% micro particle steel slag sized 1,7 µm	77,54 ab
F= 5% micro particle steel slag sized 1,7 µm	79,58 ab
G= 6% micro particle steel slag sized 1,7 µm	78,26 ab
H= 7% micro particle steel slag sized 1,7 µm	85,54 b
I= 8% micro particle steel slag sized 1,7 µm	84,99 b
J = 9% micro particle steel slag sized 1,7 µm	85,80 b
K= 5 % of steel slag 200 mesh sized	76,46 ab

Note: Same lettters indicates no difference of the value between the treatments with Duncan Multiple Range Test 5%

P-fixation makes P unavailable for plant. It happened in the soils if there are positive charge ions like Al^{+3}, Fe^{+2} and Fe^{+3} fixed the negative phosphate anions or $H_2PO_4^{-1}$ [12]. It can be seen in Ultisols, include Ultisols in this research with active Aluminum 1.33 $cmol.kg^{-1}$ (Table 1). The silicate (SO_4^{-1}) content in steel slag was expected can replace phosphate in the fixed aluminum site, and reduce P-fixation and subsequently converted into available P.

The interesting phenomenon was seen that actually P-fixation was decreased with 2 and 3% dosages, eventhought the decreased were unsinificantly different with control and with 1% dosage. It indicated that the expected reaction of silicate from steel slag succed in releasing fixed P in Al. Increasing dosage was expected decreased more fixed P, but factually increasing dosage till 9% even increased P-retention that unsignificantly different with control. Decreasing

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P-fixation was more difficult than increasing soil pH. The difficulties in changing soil reactions was explained by the soil buffer capacity, that defend the soil condition against the amendment. The theory related to the mechanism of phosphate fixation is that phosphate ions in soil soluiom are deposited and unavailable for plant.

3.4. Available P

The result of availbe P after incubation is presented in Table 5. The available P prior to the treatment was 6.92 $mg.kg^{-1}$ (Table 1). Micro particle steel slag was expected can increase available P. After two months incubation, the change available P can be seen in the Table 5. It can be obeserved that the treatments with micro particle steel slag significantly increased available P. The treatments themselves however were not significantly different each other.

Table 5. Available P after 2 months incubated with several dosages micro particle steel slag

Treatments	Available P ($mg.kg^{-1)}$
A= Control (without steel slag)	9.54 a
B= 1% micro particle steel slag sized 1,7 µm	14,12 c
C= 2% micro particle steel slag sized 1,7 µm	13,42 bc
D= 3% micro particle steel slag sized 1,7 µm	12,55 bc
E= 4% micro particle steel slag sized 1,7 µm	11,81 bc
F= 5% micro particle steel slag sized 1,7 µm	13,09 bc
G= 6% micro particle steel slag sized 1,7 µm	12,77 bc
H= 7% micro particle steel slag sized 1,7 µm	11,57 ab
I= 8% micro particle steel slag sized 1,7 µm	11,88 bc
J = 9% micro particle steel slag sized 1,7 µm	12,27 bc
K= 5 % of steel slag 200 mesh sized	13.37 bc

Note: Same lettters indicates no difference of the value between the treatments with Duncan Multiple Range Test 5%.

Available P is a concept that consist of those P-reserved that can be utilized by plant during their cycle. Phosphorus ions are available for plant as monophosphate ion (H_2PO4^{-1}) and biphosphate ion ($HPO4^{-2}$) which are more available in neutral to alkaline soil. In acid soil with pH of about 5.5 or lower, available P for plant is also lower. Tricalcalcium phosphate $Ca_3(PO4)_2$ in rock phosphate become less available to plant in acid soils. Phosphate remains predominantly in acid soil as aluminium and iron phosphate and in neutral to alkaline soil as calcium phosphate. Solubility of rock phosphate may be enhanced specially in acid soil by using soil amendment [13] like lime or dolomite and other compound that can release anions other that phosphate, like silacate.

4. CONCLUSION

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The research concluded some conclusion:

- Steel slag is not a waste product due to still can be used in several field, include agriculture.
- Using steel slag in agriculture, steel slag has to be powdered to micro sized or mesh sized.
- In Ultisols, steel slag can increase soil pH, decrease P-fixatiom and increase available P.

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