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Research Article
Effect of Humic Subtances Produced from Lignite and Straw Compost on Phosphor Availability in Oxisols

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Abstract
Background and Objectives: In Oxisols, soluble inorganic phosphorus is fixed by aluminium and iron. Humic substances is an extraction of organic matter contains functional compounds which could adsorp Al become organo-mineral. It could be more effective for time, cost and amount of organic matter by using humic substances. This study was conducted to improve phosphorus availability using humic substances from lignite and rice straw compost. **Materials and Methods:** The treatments consist of lignite 300 ppm (H1), lignite 600 ppm (H2), lignite 900 ppm (H3), straw compost 300 ppm (H4), straw compost 600 ppm (H5), straw compost 900 ppm (H6) with 3 replications using completely randomized design. The parameters measured in this study were some of the chemical properties of soil, mainly phosphorus availability and plants growth. **Results:** The findings suggested that the humic substances could altered soil chemical properties and the humic substances from rice straw compost 900 ppm is the most effective increased available phosphorus, soil pH, CEC of clay, C-organic and decreasing exchangeable aluminium. But, based on maize growth results such as plants height and dry matter weight, the plants still showed phosphorus deficiency symptoms. **Conclusion:** These results indicated that needed higher dose of humic substances above 900 ppm to fixed the chemical properties of Oxisols. Humic substances from rice straw compost more effective than lignite to improve available phosphorus in Oxisols.

Key words: Humic substances, phosphorus, oxisols, lignite, rice straw compost

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Phosphorus deficiency is one of the limiting factors of acid soil, such as Oxisols due to high phosphorus (P) adsorption by aluminium (Al) and iron (Fe) that influence acidity soil and P fixation[1-3]. Organic matter could reduce contains of Al and Fe in Oxisols so make phosphorus in available condition. The beneficial effect of organic amendments on P bioavailability in soil was directly associated with the presence of humic substances in these materials[4-6]. Humic substances consist of fulvic acid and humic acid which have OH phenolic and COOH compounds[1,2]. Based on result of infrared spectroscopy, COOH (precisely COO^-) holding important role on metal ion complexing by humic substances[7-12].

Pettit *et al*.[13] stated that carbon organic content of acid soil such as Oxisols was low. Therefore, treatment of acid soils with plant residue composts, urban waste compost, manures and coal-derived organic products have all been used to increase soil pH, including availability of phosphorus[12]. Mature organic matter consisted of 65-75% humic substances and 25-35% non humic[14], contain functional compounds that could form a complex of organo-mineral in acid soil[1,14,15]. Humic substances were believed to maintain the stability of the soil reaction, adsorption/fixation/chelate of cation, thereby increasing the availability of water and plant nutrients[16]. In the other words, to improve phosphorus availability in Oxisols, needed the functional compounds like humic substances.

Turgay *et al*.[17] reported that Humic Acid (HA) has a promising natural resource showing persistent effects on plant growth promotion, nutrient uptake and soil nutrient status. These results similar with Sharif *et al*.[18] reported in detailed that the positive effect of humic substances on enhancing plant growth was attributed to their promoting effects on soil physical, chemical and biological-biochemical characteristics and increasing soil quality in general and hence providing better plant growth. Humic acid was a naturally occurring polymeric-heterocyclic organic compound with carboxylic ($COOH^-$), phenolic (OH^-), alcoholic and carbonyl fractions extracted from various sources such as lignite, peat, coal, farmyardmanurebesides natural persistence in soil[2,17,19]. Humic acid was not only found in soil, plants, peat, natural water, rivers, sea sediments and other chemically and biologically transformed materials but also extracted from lignite, oxidized bituminous coal, leonarditeand gyttja[20]. The extractable amount of humic acid depends on organic material type, extraction agent and temperature and particle size of the substrate.

Moreover, the origin and source of humic acid was the prime parameter to obtain high purity humic acids. Lignite has highcarbon and it is easy to decay hence potentially be an alternatif for carbon (C) sources for plants. Low grade lignite seem to be the major source of humic acid[21,22]. Straw compost as one of sources of organic matter should applied and incubated for a long time for make it function as soil ameliorants. For efficiently of costs, time and amount of organic matter used humic substances could be considered. Furthermore, it is easy to find its sources, such as straw and other crops residue so that farmers could use wastes from their farms as organic fertilizer.

Therefore, the objective of this study was to know the effect of humic substances from lignite and rice straw compost to improving phosphorus availability of Oxisols. The results of this study could be considered to manage Oxisols for sustainable agriculture mainly in the humid tropics of Indonesia.

MATERIALS AND METHODS

Study site: The research was conducted from October, 2017 until March, 2018 in Experimental Farm (green house), Faculty of Agriculture, Hasanuddin University, South Sulawesi, Indonesia. Soil samples were analyzed in Soil Laboratory of Department of Soil Science, Faculty of Agriculture, Hasanuddin University. Soil samples of Oxisols were taken from Malili, District of East Luwu, Indonesia on coordinate geography S 2°34'54.768", E 121°5'27.1428" (Fig. 1).

Experimental design: This research was arranged in a completely randomized design with three replications for 6 treatments so there were 21 units. The treatments consist of lignite 300 ppm (H1), 600 ppm (H2), 900 ppm (H3), rice straw compost 300 ppm (H4), 600 ppm (H5), 900 ppm (H6). There are soil parameters and plant parameters.

Soil analysis: The soil parameter used are soil pH, CEC and CEC of clay, C-Organic, available P, exchangeable Al, bulk density and soil texture. For soil, chemical parameter was analyzed before and after treatments, then plant parameter was analyzed plant height and dry matter weight. The pH of soil in a 1:2.5 soil/water mixture was analyzed according to Richards[23], organic matter of the soil by a modified Walkley–Black method according to Jackson[24], particle-size distribution according to Bouyoucos[25], soil-available P by the Bray method according to Bray and Kurtz[26] and classification of P_2O_5 value according to Hill Laboratories[27]; exchangeable Al

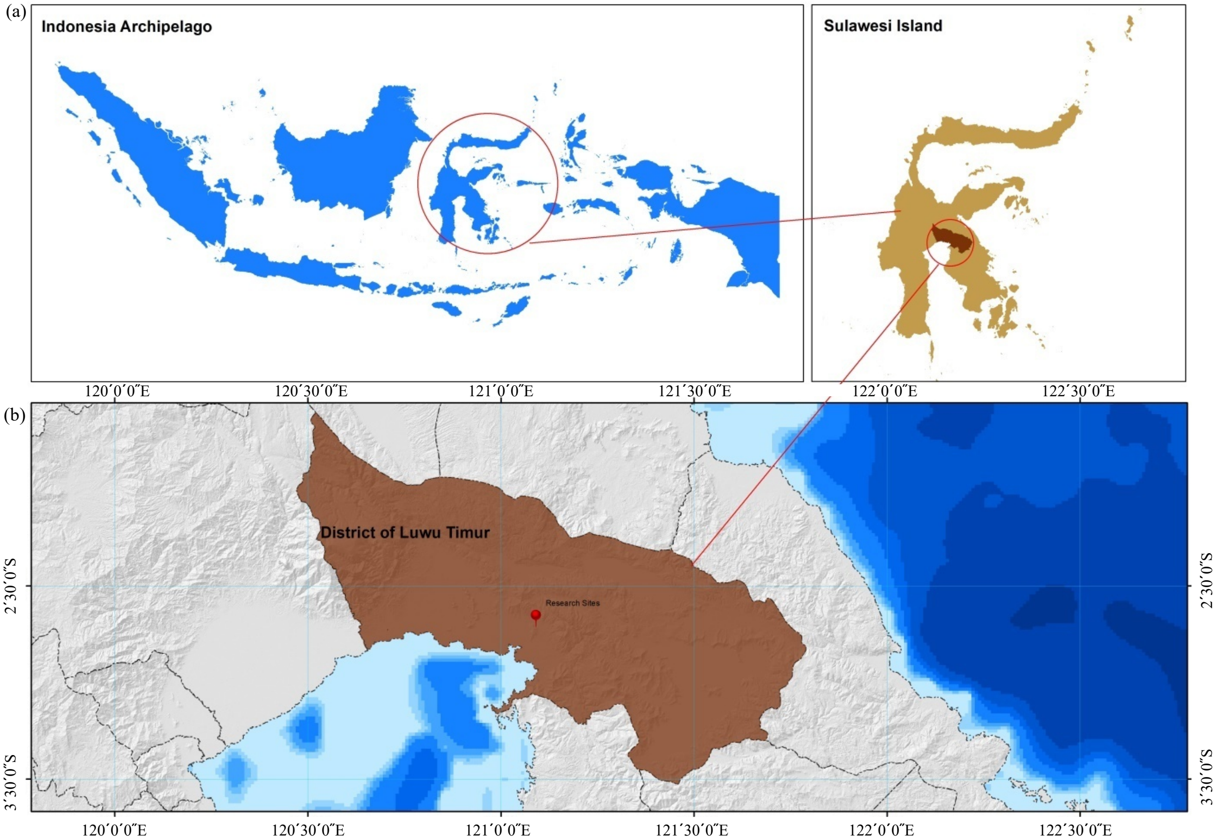

Fig. 1(a-b): Location of the study site, (a) Indonesia, (b) Malili, district of East Luwu, South Sulawesi
Source: Analysis by using Geographical Information System

were determined using the titrimetric method according to McLean[28], Burt[29] and Carter and Gregorich[30], method for determining CEC using 1 M ammonium acetate (NH_4OAc) at pH 7.0.

Data analysis: For some soil and plant characteristics were analyzed in Duncan's Multiple Range Test (DMRT) at 5% probability level using IBM SPSS statistics version 22.

RESULTS

Characteristics of oxisols: The soil analysis results in Table 1 showed that some chemical and physical properties of the Oxisols before humic substances treatments. Soil type of the site has classified as *Xanthic hapludox*. The soils have an oxic horizon with 30% of clay, 62% of silt and 8% of sand.

Based on the Table 1, the pH H_2O and KCl value of Oxisols from east Luwu Indonesia classified as acid, the exchangeable-Al of Oxisols was 3.52 cmol kg^{-1} classified very high, P_2O_5 value was 9.42 ppm classified as low. The value of soil CEC was 7.45 cmol kg^{-1} and CEC of clay 34.57 cmol kg^{-1} clay indicated the low of capacity of the soil to exchangeable the cations. This soils have a percentage of carbon organic very low (0.24%) and soil texture classified as silty clay loam with bulk density value was 1.2 g cm^{-3}.

Table 1: Some soil properties of Oxisols from East Luwu, Indonesia

Parameters	Results
pH-H_2O	5.21
pH-KCl	4.99
Exchangeable Al (cmol kg^{-1})	3.52
P_2O_5 (ppm)	9.42
CEC (cmol kg^{-1})	7.45
CEC of clay (cmol kg^{-1})	34.57
C-organic (%)	0.24
Bulk density (g cm^{-3})	1.2
Soil texture (Silty clay loam)	
Sand (%)	8.0
Silt (%)	62.0
Clay (%)	30.0

Soil characteristics after treatments: Soil data on the Table 2 showed chemical properties and physical properties of Oxisols from Malili, East Luwu, Indonesia after humic substances treatments.

Table 2: Some properties of Oxisols after humic substances treatments

	pH						
Treatments	H_2O	Kcl	Al-dd (cmol kg^{-1})	Available P (ppm)	CEC (cmol kg^{-1})	CEC of clay (cmol kg^{-1})	C-org (%)
K	5.21^{ab}	4.99^{a}	3.52^{c}	6.98^{a}	7.45^{a}	24.83^{a}	0.24^{a}
H1	5.15^{a}	5.14^{a}	3.27^{c}	7.07^{ab}	7.85^{a}	26.17^{a}	1.29^{b}
H2	5.15^{a}	5.12^{a}	2.94^{bc}	7.16^{abc}	8.57^{b}	28.57^{b}	1.32^{b}
H3	5.13^{a}	5.10^{a}	2.81^{bc}	7.24^{abc}	8.90^{bc}	29.67^{b}	1.55^{c}
H4	5.15^{a}	5.13^{a}	2.09^{ab}	7.42^{bcd}	9.30^{c}	31.00^{c}	1.70^{d}
H5	5.40^{bc}	5.33^{b}	2.09^{ab}	7.50^{cd}	10.17^{d}	33.90^{d}	1.82^{de}
H6	5.48^{c}	5.37^{b}	1.76^{a}	7.68^{d}	12.43^{e}	41.43^{e}	1.92^{e}

K: Control, Values followed by the same letter in a column are not significantly different at $p<0.05$

Table 3: Maize plants growth

Treatments	Plants height (cm)	Σ leaves	Dry matter weight (g)
K	8.52^{a}	3.11^{a}	0.30^{a}
H1	9.17^{ab}	3.45^{ab}	0.47^{ab}
H2	9.99^{bc}	3.33^{ab}	0.93^{abc}
H3	10.91^{cd}	3.50^{ab}	1.10^{bc}
H4	10.99^{cd}	3.75^{bc}	1.60^{c}
H5	11.37^{cd}	3.92^{bc}	1.60^{c}
H6	11.93^{d}	4.33^{c}	2.37^{d}

K: Control, Values followed by the same letter in a column are not significantly different at $p<0.05$

Soil data on the Table 2 showed the highest soil pH was present in the H6 treatment, i.e., 5.48 and 5.37. The H6 treatment was significantly different from K, H1, H2, H3 and H4. Soil pH after treatments was classified as acid. If compared with pH before treatment, pH has increased but still less than 5.5. The H6 treatment showed the lowest Exc.-Al soil value, i.e., 1.76 cmol kg^{-1}, it was significantly different from K, H1, H2 and H3 but not significantly different from H4 and H5. Al-dd has improved from before treatment but the value of Al-dd is still high even in H6. This was related to soil pH. The highest available P was present in the H6 treatment with a value of 7.68 ppm which is significantly different from K, H1, H2 and H3 but not different from H4 and H5. Although H2 and H3 were not significantly different with H4 and H5 but H2 and H3 were significantly different with H6. The p-value of soil less than 10 ppm, would classify as low value. The highest CEC and CEC of clay were found in the H6 treatment of 12.43 and 41.43 cmol kg^{-1} significantly different from all treatments.

Plants growth: The Table 3 showed the maize growth that indicated with plants height, sum of leaves and dry atter weight.

According to the Table 3, the highest plant found in H6, i.e., 11.93 cm were significantly different from K, H1 and H2 and not significantly different from the H3, H4 and H5. The H6 treatment showed the highest number of leaves, having an average leaf number of 4.33, which was significantly different from K, H1, H2 and H3. The treatment has an average dry weight of the heaviest crop was H6 which was significantly different from all treatments.

The results in Table 3 showed that the best treatment was found in H6, which was significantly different from other treatments. Based on the average height of the plant, humic compounds from straw compost have higher plants than humic compounds from lignite.

However, viewed all growth of maize for each treatment was considered poor, even for H6. Until 35 day after planting, plant height was still 12 cm. These results related to soil characteristics after treatment, which was still considered poor in terms of its chemical properties.

The H6 showed the best treatment having an average dry weight of 2.37 g. The treatment of H6 was significantly different from all treatments. The H6 gave the best dry weight yield compared to other treatments. When viewed from the average dry weight of plants, humic compounds from straw composts give heavier dry weight than lignite.

DISCUSSION

Oxisols are highly weathered soils of the tropics[31,32]. In the tropics with high rainfall contribute to the soil acidification by natural causing parent materials to be acidic due to leaching of cations[33,34]. The increased soil acidity causes solubilization of Al, which is the primary source of toxicity to plants at pH below 5.5[35]. The pH H_2O of Oxisols from Malili, East Luwu was 5.21 and pH KCl was 4.99 meant to acidity of this soils. The available P value was 9.42 ppm (Table 1) indicated that the P fixated by Al. It was meant that Oxisols from Malili, East Luwu have the poor quality of soil chemical properties for agriculture but have a potential with certain soil management. The high exchangeable-Al would make the availability of P in Oxisols classified very low[36] due to fixated soluble Al and oxyhydroxide Al and formed Al-P that was not soluble. Based on Von Tucher *et al.*[37] research, there is an interaction between soil pH and available P in the soil that may affect dry weight of the plant, on the soils with pH 5.3 yielding the lowest dry weight of the plant and the lowest dissolved P than the soil with pH 6.2 and 6.0. Al cation will be more affected by making low pH soil. As pH decreases, solubility and toxicity aluminum (Al) increased in the soil[38]. Exc-Al was associated with the level of P available in the soil for plants. Chemical processes that occur are Al and Fe oxides increase the retention of P. This reaction was occur depending on the acidity of the soil. In acid soils, according to Ohno and Amirbahman[39], P was bound by strong absorption energy such as iron/aluminum oxide and Fe/Al hydroxide resulting in Al-P bonding.

Soil texture categorized as silty clay loam that meant the proportion of sand, clay and silt ideal for growth media. According to research of Chau *et al.*[40], comparing with sand, loamy sand, sandy loam, silty loam, loamy and silty, silty clay loam has particle diameter between 0.001-0.9 mm and was dominated 0.1 mm while diameter of another soil texture were dominated <0.1 mm and >0.1 mm, because of that porosity proportion of soil with silty clay loam more ideal for plant growth. There is no compaction indicated from the value of bulk density in this Oxisols. Generally, the bulk density of less than 1.6 g cm^{-3} would not inhibit the root growth[41]. According to McKenzie *et al.*[41], soils dominant particle of silt and clay have the range of bulk density which supports the plant growth are 1.1-1.6 g cm^{-3}.

The plants without P treatment showed symptoms of phosphorus deficiency. The research of Plenet *et al.*[42] showed that the strong relationship between phosphorus and plant growth. The study of Umeri *et al.*[43] on the comparison of macro elements of N and P in influencing crops if a limiting factor showed that the average height of plants given N fertilizer without P has a lower value than plants given P fertilizer without N.

The increased of C-organic content due to the treatment was given was organic matter material. The results research of Edi[44] was showed the influence of humic compounds made from lignite and P fertilizer on the Oxisols soil chemical properties. The study showed an increase in the C-org content along with increased doses of the given humic substances. The content of C-org of soil with humic compounds higher than without the application of humic compounds ranging from 0.6-0.7%. Another study conducted by Daur and Bakhashwain[45] showed that there was an increase in C-organic soil from 2.01-2.14%, which was caused by the content of lignite, which was carbon (C), as well as if the compound humate material comes from organic fertilizers such as compost. The higher the dose of the given humate compound, the higher the growth of the plant height. This is due to the higher supply of functional clusters of organic materials. In accordance with the study of Daur and Bakhashwain[45] showed that the dose of humic acid significantly affected the height of maize and the highest dose had significantly different effect with low dose and control. Increased growth of maize plants was due to improvement by humic acid to soil conditions around roots, where humic acid maintains the provision of nutrients and water to plants compared with controls.

Especially for the content of Exc.-Al and available P in the soil for plants. The range of P-available on soil after treatment was 6-7 ppm. According to Kelling *et al.*[46], the optimum requirement of maize on phosphorus (P) was 9 to 15 ppm, soil P in the range of 5 to 8 ppm was still low for maize so that plant growth will not be optimal even deficiency. When viewed from the physical condition of plants, dwarf plants or slow growth, both from the growth of the top (shoot) and bottom (roots), which was a symptom of deficiency P. It was because the high Al content in the soil could not be overcome by the addition of humic compounds with dose which has been determined because Al still has a chance to bind P so that P could not be available for plants. According to Krstic *et al.*[38], Al concentrations can be exchanged which are likely to toxic to the plants can be lower absorbed by the plant than its presence on the planting medium. The high content of Al on the plant body medium could not toxic to the plants because it was bound P and settles.

Although H6 showed the highest value, the CEC soil value was still relatively low[47]. The CEC value of the soil associated with the Al content could be exchanged in the soil. Many related studies showed that soil cation exchange rate capacity can be a parameter of toxicity level of Aluminum[48-51] so that the low level of CEC was due to the exchangeable aluminum content which was still relatively high. The treatment with the highest C-organic content was present in H6 at 1.92% which was classify as low content[47].

The higher the dose of the humic compound given, the higher the dry weight value of the maize. Leventoglu and Erdal[52] studies showed similar results in his research on the application of humic compounds in maize grown on alkaline soils. The results showed that the average dry weight of maize increased consecutively in doses of humic compounds 0, 500, 1000 and 2000 ppm. In the study the maize was planted until 60 days after planting but the dry weight of the plant is still around 2-3 g pot^{-1}, in other words, the plant showed dwarf symptoms and was suspected of deficiency P. it was proved that although at a dose of 2000 ppm, humic compounds were still not able to provide good plant growth on soils with extreme pH. When viewed from the dose used in this study, the maize in this study experienced the similar thing, P deficiency, resulting from the still high exc.-Al level on the soil binding P so that P could not be available for the plant. Although the dry weight of the plant increased in all treatments compared with the controls, the plant still showed poor growth in dry weight of the plant that was incompatible with the age of maize growing.

CONCLUSION

Based on the result of the research, it can be concluded that humic substances from straw compost dose 900 ppm gives the best influence for the availability of P in Oxisols soil from humid tropics of Indonesia and improve other chemical properties constantly. The impact of humic substances from straw compost to soil chemical properties better than humic substances from lignite. Changes in the availability of P were still low and the plant growth response to availability was still poor so that it was required over of 900 ppm to improve the Oxisols soil chemical properties.

SIGNIFICANCE STATEMENT

The study discovered the effect of humic substances from lignite and rice straw compost to the availability of soil P in the Oxisols that problemed with soil chemistry including acid soil pH, low CEC and clay CEC, base saturation and high exchangeable Al. These findings might be used as reference for other researchers to determine the amount of humic acid needed to be applied in the Oxisols. This study will help the researchers to get solutions about how to manage Oxisols in the tropics area effectively using organic material sources.

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