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Soil pH and Solubility of Aluminum, Iron, and Phosphorus in Ultisols: the Roles of Humic Acid

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ABSTRACT

Soil reaction (pH), aluminum (Al), iron (Fe) and phosphorus (P) are the soil properties that are related to each other. Their role on the growth and development of plant is very significant. Liming and organic mater are the soil amendments that are frequently used to increase soil pH and P solubility and to suppress the solubility of Al and Fe in the soil. Humic acid is one of the organic fractions which is presumed has a role and is closely related to the changes in the soil chemical properties as mentioned above. Information about the role of humic acid on the soil pH, the solubility of Al, Fe, and P, especially in upland acidic Ultisols is still limited. This study aimed to provide empirical data on the role of various humic acids to soil pH and the solubility of Al, Fe, and P, specifically in upland acidic Ultisols. The study was a laboratory experiment with a single factor which was set by a completely randomized block design and was conducted in two sets of experiments. The first experiment was intended to study the roles of various humic acids derived from several sources (commercial humic acid, humic acids extracted from composted chicken manure, humic acids extracted from composted cow manure, and humic acids extracted from composted goat manure) on the soil pH and solubility of Al, Fe, and P. The second experiment was aimed to study therelationship patterns between application of humic acid (sold commercially) on soil pH and solubility of Al, Fe, and P. The results showed that humic acid was able to increase the soil pH and solubility of phosphorus, while it suppressed the solubility of iron and aluminum with linear patterns of relationships. Humic acid that was sold commercially, at the same amount of C-organics, had greater in increasing the soil pH, solubility of phosphorus, and suppressing the solubility of iron and aluminum in the soil, roles than those derived from organic matter of compost extracts and from organic matter of compost.

Keywords: Aluminum, humic acid, iron, pH, phosphorus

INTRODUCTION

Ultisol is is a type of soil that generally dominant in acidic upland farming areas in Indonesia (Leiwakabessy 1989). The main constraints in the development of this agricultural land are low pH, high P fixation, high content of Al, Fe and Mn, and low cation exchange capacity (Prasetyo and Suriadikarta 2006; Yusran 2008). Application of organic matter can improve soil pH and suppress the solubility of Al (Suntoro 2001) and can overcome the toxicity of Al and Fe (Gupta 1997), and it will reduce the activity of Al and Fe by the phosphate fixation (Kononova *et al*. 1986; Agbenin 2003). One of the stable organic fractions (humic substances) which have the ability to form complex compounds with metal ions dissolved in the soil is the humic acid compounds (Hayes and Swift 1990; Stevenson 1994; Tan 1995). Humic acids contain of active functional groups such as carboxyl, phenol, carbonyl, hydroxide, alcohols, acids, quinones and metoxil, where the anions are actively and effectivel react with Al and Fe to form organo-metallic complexes (Kononova *et al*. 1986). The dominant effort made to raise the pH, reducing P fixation, pressed alumunium and iron solubility in the soil is by liming and adding organic materials as reported Gupta (1997); USDA (1999); Suntoro (2001); Rima (2002); Subandi (2007); and Arifin *et al*. (2009). This condition give the opportunity to look for other materials that have the same properties as lime and organic matter and one that is humic acid.

The aims of this study was to provide empirical data on the roles of various humic acids on soil pH and the solubility of Al, Fe, and P, especially in upland acidic Ultisols.

MATERIALS AND METHODS

Study Site and Design

The soil is Ultisols taken composite from Pondok Empat Village Loktabat District, Banjarbaru City, South Kalimantan Province. The study was a single factor pot experiment conducted in a green house and arranged by using a completely randomized design (CRD). Each pot contains 1 kg of soil experiment which was given 300 mg kg^{-1} Al and 300 mg kg^{-1} Fe ($AlCl_3$ and $FeCl_3$). Soil moisture in the pot was maintained at 60% field capacity and incubated for 3 weeks after being given treatment. Each treatment was repeated 3 replications.

Experimental Set Up and Observation

At the first set of experiments the treatments were applied to see the roles of pH and humic acid on the solubility of Al, Fe, and P. The humid acid treatments derived from several sources, namely: without ahumic acid (TA), 0.5g pot^{-1} of humic acid sold commercially (AH), 4.18 g pot^{-1} of compost from cow manure (KTS), 4.74 g pot^{-1} of chicken manure compost (KTA), 5.14 g pot^{-1} of goat manure compost (KTK), 20 ml pot^{-1} humic acids extracted from composted cow manure (EHS), 22 ml pot^{-1} humic acids extracted from composted chicken manure (EHA), and 24 ml pot^{-1} humic acids extracted from composted goat manure (EHK). Base calculation of the dose for each treatment is to equate the value of organic C content, which is the value of organic-C content contained in 0.5 grams o fhumic acid sold commercially.

At the second set of experiments, the treatments were applied to see the pattern of the relationship between the amount of humic acid (sold commercially) applied with pH and the solubility of Al, Fe, and P. The treatments were: without a humic acid (AH0), 1 g pot^{-1} humic acid (AH1), 2 g pot^{-1} humic acid(AH2), 3g pot^{-1} humic acid (AH3), 4 g pot^{-1} humic acid (AH4), 5 g pot^{-1} humic acid (AH5), 6 g pot^{-1} humic acid (AH6), and 7 g pot^{-1} humic acid (AH7). Variables observed int his study were: pH (H_2O) (Glass electrode method 1:2.5), Al-soluble (1 *N* KCL percolation-titration), dissolved Fe (Extraction NH_4OAc. 1 *N* pH 4.8-Spectrophotometer), and available P (Bray-Extraction Spectrophotometer) (Balai Penelitian Tanah 2005).

Data Analysis

Data obtained were analyzed by analysys of variance (ANOVA) and continued by Duncan Multiple Range's Test (DMRT) at a level 0f 5%. Regression and correlation analysis were run for study the relationship between observation variable.

RESULTS AND DISCUSSION

The result of prelimenary soil analyses showed in table 1 and data from the analysis of the addition of humic acid (source of humic acid) to changes in pH, available P, Al-soluble and dissolved Fe in the soil can be seen in Table 2.

The addition of humic acid was able to increase the available-P and reduce the solubility of Al and Fe in the soil (Table 2). The high solubility of Al and Fe which accompanied by the hydrolysis processed to many hydrogen ions are released into the soil solution that resulting in acidic soil. This condition causes the P compounds become insoluble and not available in the soil solution because it was fixed by Al and/or Fe (Bohn *et al.* 1985: Tan 1995).

Humic acid contains functional groups of hydroxyl and carboxyl which may bind Al and Fe soluble (Andrian 1990; Antelo *et al.* 2007) so that their activities in the soil decrease sand the hydrolysis (as in the reactions mentioned above) to reverse direction, namely towards the left, which means consuming H^+ ions are soluble in resulting soil concentrations of H^+ ions in the soil solution decreased and increased soil pH (Winarso *et al.* 2010). This is inline with what is proposed by Tan

Table 1. Soil and ameliorant properties.

Parameters	Value
Texstur:	
Sand (%)	57.39
Silt (%)	25.00
Clay (%)	17.61
pH	4.02
Exch-Al (cmol kg^{-1})	1.50
Soluble Fe (mg kg^{-1})	26.80
CEC (cmol kg^{-1})	16.80
Organic-C- (%)	0.66
Humic acid Organic-C (%)	3.46
Humic acid Organic-C extracted from chicken manure compost (%)	4.40
Humic acid Organic-C extracted from cow manure compost (%)	3.80
Humic acid Organic-C extracted from goat manure compost (%)	3.40
Total-P (mg kg^{-1})	12.34
Available-P (mg kg^{-1})	0.29
Total-N (%)	0.08
Ca-exch. (cmol kg^{-1})	0.85
Mg-exch. (cmol kg^{-1})	0.35

Table 2. Effect of humic acid on pH, available-P, Al-soluble and insoluble Fe in the acidic soil of upland farming.

Treatment	pH	Available-P (mg kg^{-1})	Exch-Al (cmol kg^{-1})	Soluble-Fe (mg kg^{-1})
TA	3.53 a	0.05 a	4.70 a	39.35 a
AH	4.19 d	0.12 d	1.90 d	20.07 d
EHK	3.69 c	0.08 c	3.10 c	26.78 c
EHS	3.73 c	0.09 c	2.80 c	25.80 c
EHA	3.71 c	0.09 c	2.50 c	24.90 c
KTK	3.60 b	0.06 b	4.10 b	29.90 b
KTA	3.65 b	0.07 b	3.50 b	29.70 b
KTS	3.58 b	0.06 b	4.00 b	29.50 b

TA= without humic acid. AH= commercial humic acid; EHK= Humic acid extracted from goat manure compost; EHS= Humic acid extracted from cow manure compost; EHA= Humic acid extracted from chicken manure compost; KTK = goat manure compost; KTA= chicken manure compost; KTS= cow manure compost. Data followed by the same letter in the same column are not significantly different based on DMRT at 5% level.

(1995) and Suntoro (2001) which states that humic acid has a specific characteristic that has the ability to interact with metal ions, oxides, hydroxides, mineral, and organic materials, including toxic pollutants which are able to lower the soil pH. The reduced activity of Al and Fe in the soil solution due to reactions with hydroxyl and carboxyl functional groups of humic acids to form organo-metal complexes (Hayes and Swift 1990; Stevenson 1994; Tan 1995; Ulfin and Setyowati 2007) were capable of inhibiting the activity of Al and Fe in the P fixation, so P-soluble and available P in soil is enhanced (Kononova *et al.* 1986; Minardi 2006). The relationship between the amount of humic acid added and changes in pH and available P in soil (Figure 1) shows a positive linear relationship patterns, and a negative linear relationship to Al-soluble (Figure 2) and dissolved Fe (Figure 3) in the soil. The relationships were according to the equation Y=0.1147X + 3.6093 with a coefficient of determination (R^2) of 0.9979 for soil pH, Y= 1,273X + 0.0339 with a coefficient of determination(R^2) of 0.9906 for the P-available and Y= 3.0583 + 0.4131X with coefficients of determination (R^2) of 0.9915 for Al-soluble,as well as Y=35.578-2.5825X with coefficients of determination (R^2) 0.9862 for the dissolved Fe. This condition is clearly strengthen the role of humic acids in increasing pH and P

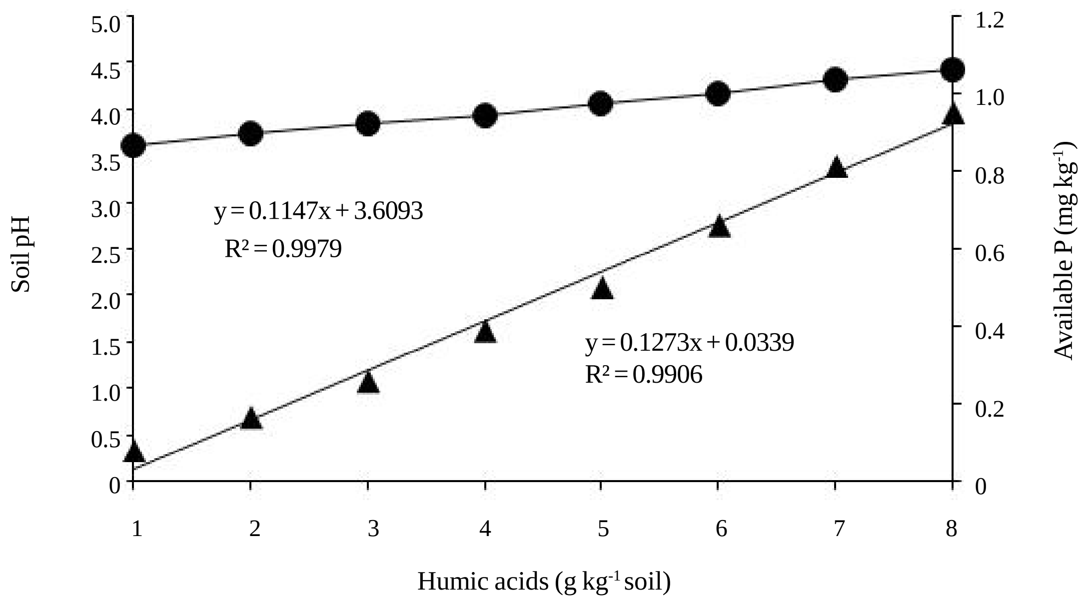

Figure 1. The relationship pattern between the amount of humic acid applied and changes in pH and available P in soil. —●— = soil pH and —▲— = available P.

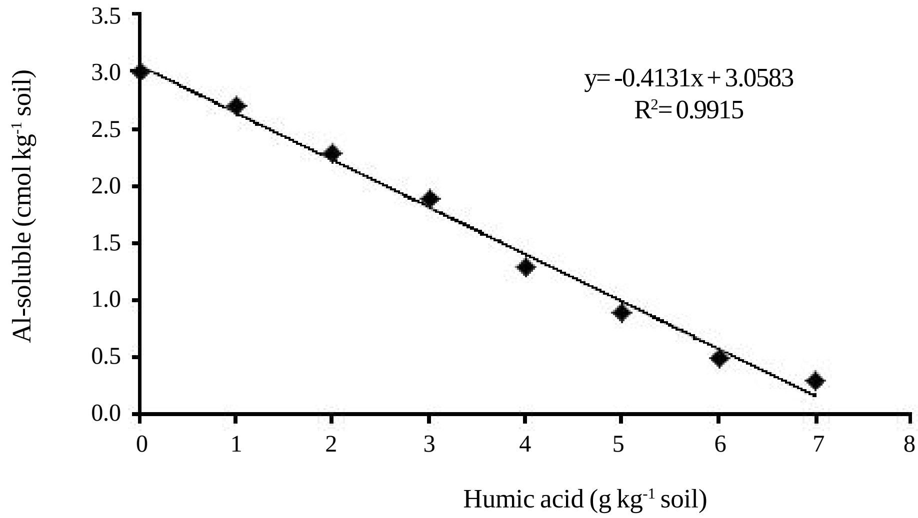

Figure 2. The relationship between the amount of humic acid applied and changes in Al-soluble

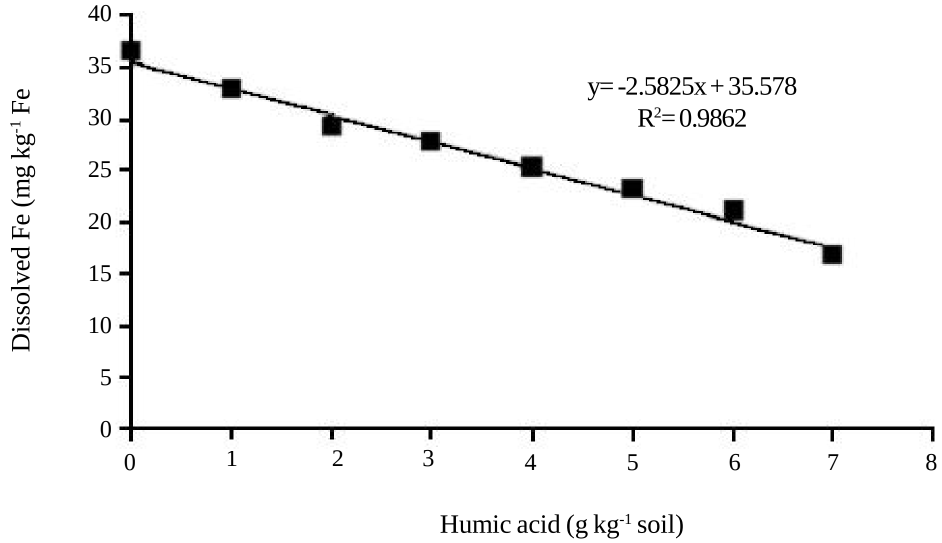

Figure 3. The relationship between the amount of humic acid applied and changes in dissolved Fe.

availability, as well as decreasing Al- soluble and dissolved Fe in the soil.

The relationships between humic acid applications and an increase in the value of pH and P availability, as well as a decrease the solubility of Al and Fe in the soil as shown in Figure1, Figure 2, and Figure 3, indicate that the more humic acid content of a material, the greater the role of the state as mentioned above. This is why the treatment of humic acid sold commercially was able to produce the highest values of pH and P-values in the soil, on the contrary, it was able to produce low value Al-soluble and dissolved Fe compared to the treatment of organic material in the form of compost applications (goat manure, chicken manure, and cow dung). Humic acid extract ed from compost (goat manure, chicken manure, and cow manure) and untreated soil humic acid (Table 2).

Treatment of type organic compost application (goat manure, chicken manure, and cow manure) and of extracts from composted organic materials (goat manure, chicken manure, cow manure), each of which did not result in differences in pH values, P-available values, the Al-soluble and Fe-soluble in the soil. However, the treatments of organic compost extract application (goat manure, chicken manure, and cow manure) produced higher pH values and P-values; on the contrary, it produced value-soluble Al, and dissolved Fe lower than that applied to the compost organic matter (goat manure, chicken manure, and cow manure). Application of multiple-dose treatment refers to the number of C-organic content (organic C content of each treatment are created equal). Under these circumstances, it is assumed that the humic acid content in each treatment (the treatment of humic acid extracts of several types of compost or organic material from the treatment of type compost) is the same amount. The results (Tabel 2) showed that humic acid contained in each of these treatmet substances are not the same, despite having the same C-organic content. Humic acids contained in the compost organic matter (goat manure, chicken manure, or cow manure) seems to have the same amount so that the impacts of changes in soil pH, Al-soluble, P-available and dissolved-Fe were not different, and as well as the case in humic acid extracts derived from organic compost material (goat manure, chicken manure, and cow manure).

Humic acid contents in the compost treatment of organic materials (manure, chicken manure, and goat manure) appear slower than that contained in the extract of compost organic matter (cow manure, chicken manure, and goat manure); thus, an increase in the pH value and P-available, as well as the decrease Al-soluble dissolved Fe in the soil due to compost treatment of organic material (manure, chicken manure, and goat manure) was lower than that contained in the extract of compost organic matter (cow manure, chicken manure, and goat manure).

Application of organic materials (all types of organic matter) into the soil will have an impact on changes in soil properties after organic matter is decomposed (Tan 1995; Suntoro 2001). Humic acid extracts derived from organic matter, having applied into the soil will work according to the characteristics as mentioned by Tan (1995). Whereas the organic material once applied into the soil will require time to be beneficial to the soil so that within a certain period the role of extract the organic material would be better than the role of organic material as shown in Table 2.

CONCLUSIONS

From these results it can be concluded that humic acid can increase the pH and available P in soil with a pattern of positive line a rrelationship and can reduce the Al-soluble and dissolved Fe in the soil with a pattern of negative relationship. The roles of humic acid in increasing pH and available P and lower soluble Al and Fe in soil are inrespectively: the sold commercially humic acid > humic acid from compost extract organic material (cow manure, chicken manure, and goat manure) > composted organic material (cow manure, chicken manure, and goat manure). Types of organic compost from cow manure, chicken manure, and goat manure gives an equal roles in raising the pH and available P, as well as lower soluble Al and dissolved Fe, and similarly with the types of organic compost extracted from cow manure, chicken manure, or goat manure.

REFERENCES

Agbenin JO. 2003. Extractable iron and alumunium effects on phosphate sorbtion in a Savanna Alfisol. *Soil Sci Soc Am J* 67: 589-595

Andrian RDP. 1990. Hubungan Antara Susunan Asam Humat dan Asam Fulfat serta Kemasaman Total Bahan Organik Tanah dengan pH Tanah. Aluminium dan N Tersedia. [Skripsi]. FakultasPertanian Universitas Lambung Mangkurat. Banjarbaru.

Antelo J, F Arce, M Avena, S Fiol, R Lopez and F. Macias. 2007. Adsorption of humic acid at the surface of goethite and its competitipe interaction with phosphate. *Geoderma* 138: 12-17.

Arifin F, B Radjagukguk and BH Purwanto. 2009. Phosphate and ferrous solubility on acid sulphate soils treated with rice straw. *J Trop Soils* 14: 119-125

Balai Penelitian Tanah. 2005. Petunjuk Teknis Analisis Kimia Tanah. Tanaman Air. Dan Pupuk. Balai Penelitian Tanah Badan Penelitian dan Pengembangan Pertanian Departemen Pertanian. Bogor. (in Indonesian).

Bohn HL, BL McNeal and GA O'Connor. 1985. Soil Chemistry (second edition). John Wiley & Sons Inc. New York. Chichester. Brisbane. Toronto. Singapore. pp. 135-141.

Gupta US. 1997. Crop Improvement Volume 2: Stress Tolerance. Science Publishers. Inc. 303 p.

Hayes MHB and RS Swift. 1990. Genesis, isolation. composition and structures of soil humic substances. In: MF De Booth, MHB Hayes and A Herbilon (eds). Soil Colloids and their Associations in Aggregates. Plenum Press. New York. pp. 245-305.

Kononova MM, T Z Nowakowsky and ACD. Newman. 1986. Soil Organic matter its Nature. its Role in Soil Formation and in Soil Fertility. Permagmon Press. Oxford.

Leiwakabessy FM. 1989. Management of Acid Humic Tropical Soils in Indonesia. In: ET Craswell and E. Pushparajah (eds). Management of Acid Soils in the Humid Tropics of Asia. ACIAR Monograph No.13 (IBSRAM Monograph No.1), pp. 54-61

Minardi. 2006. Peran Asam Humat dan Fulvat dari bahan Organik dalam Pelepasan P Terjerap pada Andisol. Ringkasan Disertasi (tidak dipublikasikan). Program Pascasarjana Universitas Brawijaya. Malang.

Prasetyo BH and DA Suriadikarta. 2006. Karakteristik. Potensi. dan Teknologi Pengelolaan Tanah Ultisol untuk Pengembangan Pertanian Lahan Kering di Indonesia. *J Litb Pert* 25: 39-46.

Rima V. 2002. Acidification of soil-the indicator of chemical soil degradation process. World Congress of Soil Science 17. 14-21 August 2002. Thailand. Paper No. 10: 1-7

Stevenson FJ. 1994. *Humus Chemistry: Genesis. composition. reactio. 2*[nd] ed. John Wiley and Sons. Inc. New York.

Subandi. 2007. Teknologi produksi dan strategi pengembangan kedelai pada lahan kering masam. *Iptek Tanaman Pangan* 12: 12-24.

Suntoro. 2001. Pengaruh residu penggunaan bahan organik, dolomit dan KCl pada tanaman kacang tanah (*Arachis hypogeae,* L.) pada Oxic Dystrudept di Jumapolo, Karanganyar. *Habitat* 12: 170-177.

Tan KH. 1995. Dasar-Dasar Kimia Tanah. Gadjah Mada University Press. pp. 37-53.

Ulfin I. and D Setyowati. 2007. Optimasi kondisi penyerapan ion aluminium oleh asam humat. *Akta Kimindo.* 2: 88-90.

USDA [United State Department of Agriculture]. 1999. Liming to Improve Soil Quality in Acid Soils. Technical Note No. 8. May 1999. Independence Avenue. SW. Washington. D.C.20250-9410

Winarso S, E. Handayanto and A Taufik. 2010. Alumunium detoxification by humic substance extracted from compost of organic wastes. *J Trop Soils* 15: 19-24.

Yusran FH. 2008. Existing versus added soil organic matter in relation to phosphorus availability on lateritic soils. *J Trop Soils* 13: 23-34.