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EFFECTS OF HUMIC SUBSTANCES ON PHOSPHORUS SORPTION AND DESORPTION CHARACTERISTICS OF SOILS HIGH IN IRON AND ALUMINUM OXIDES

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ABSTRACT

Upland soils in Indonesia occupy about 75% of the total land. The upland soil in general have low phosphorous (P) availability. P low availability is caused by iron (Fe) and aluminum (Al) oxides sorption. The objective of this study was to determine the effect of humic substances derived from Andisol Lembang, west Java and Peat soil on P sorption and desorption characteristic of high Fe and Al oxides soils. Soil sample used in this study were Rhodic Eutrudox dan Typic Paleudult, from Kuaro, East Kalimantan. The results of the analysis showed that application of humic substance from Andisol resulted in the inconsistent P sorption maxima and bonding energies, while humic substance from Peat soil significantly increased bonding energies in both soils. The application of both humic substances significantly increased the standard P requirements (P sorbed at 0.2 mg kg^{-1}) in Rhodic Eutrudox, while standard P requirements in Typic Paleudult significantly increased with application of humic substance from Peat soil. The effect of humic substance from Andisol was inconsistent on P desorption, while humic substance from Peat soil significantly decreased P desorption in both soils. It suggested that P sorption and desorption characteristics were depended on characteristic of humic substances.

Key words: Andisol Lembang, Peat, Rhodix Eutrudox, Typic Paleudult

INTRODUCTION

Upland soils in Indonesia account for about 75% of the total land area (Subagyo *et al.*, 2000). Upland soils in Indonesia have low fertility level and deficient in phosphorus (P). Some of upland soils contains high iron (Fe) and aluminum (Al) oxides. From previous studies showed that Al and Fe oxides increased the P sorption (Beauchemin and Simard, 2000; Borggaard *et al.*, 1990; Hartono *et al.*, 2005; Van der Zee and Riemsdijk, 1988; Yuan and Lavkulich, 1994). P desorption is important in supplying P to plants. This process depended on several factors, among others are the amount of labile P, the amount of P in soil solution, the rate of removal of P from solid phase to solution phase, the soil organic matter, and other ions. P desorption was also significantly correlated with the bonding energy during the process of P sorption (Hartono *et al.*, 2005). Improving the availability of P in soil besides P fertilizer and liming, can also be done by application of organic matter. Soil organic matter contributes to plant growth and affect the physical properties, chemical, and biological soil (Stevenson, 1982). Tan (1998) suggested that soil organic matter can be divided into unhumified and humified materials. Humified materials is what is known as humic compounds and is considered as an end result of decomposition of plant material in soil. Today, humic compounds is a popular material to improve the fertility of the uplad soils. Therefore, research on the effect of humic substances on P sorption and desorption process is necessary.

This research sought to determine the effect of humic substances on the P sorption and desorption characteristics of Rhodic Eutrudox and Typic Paleudult upland soils in Kuaro, East Kalimantan.

MATERIALS AND METHODS

The soil samples that had high Al and Fe oxides are presented in Table 1. These two top soils samples were collected from Kuaro, East Kalimantan. Table 1 showed that the two soil samples contained total Fe and Al oxides higher than those of other upland soils observed by Hartono *et al.* (2005).

Table 1. Chemical properties and Al and Fe oxides content of Rhodic Eutrudox and Typic Paleudult

Soils	pH		Bray 1-P	Org. C	CEC	Dithionite		Oxalate		Total Fe and Al Oxides	Clay
						Fe	Al	Fe	Al		
	H_2O	KCl	mg kg^{-1}	%	Cmol kg^{-1}	......................................%......................................					
Rhodic Eutrudox	6.1	5.3	12.8	7.80	17.4	8.84	0.77	0.34	0.20	10.2	40.4
Typic Paleudult	5.1	4.4	15.4	4.87	21.8	6.99	1.51	0.28	0.66	9.44	69.9

Humic substances were extracted from both Andisol Lembang and peat soil by adding 500 mL of 0.5 mol L^{-1} NaOH to a 100 g sample of each soil and shaken for 12 h (Stevenson, 1982). After shaking, the soil samples were centrifuged to get the supernatant which is already the humic substance to be used in treating the soil samples.

Soil samples as much as 3 g of air dry weight in the centrifuge tubes were added 15 mL of humic substances from Andisol or from peat. The centrifuge tubes were incubated two days in order to achieve equilibrium. After incubation, the centrifuge tubes were centrifuged for 15 minutes at 2500 rpm to separate the soil with humic substances. Humic substances that have been separated from soil samples discarded. Soil samples in the centrifuge tubes were washed with distilled water as much as 2 x 25 mL (Setiadji, 1997).

P sorption experiment was conducted using the method of Fox and Kamprath (1970). Soil samples which had been saturated by humic substances from Andisol or Peat soil equilibrated with 30 mL of 0.01 mol L^{-1} $CaCl_2$ solution containing P with various concentrations (0-250 mg L^{-1}) in the form of KH_2PO_4 for six days at room temperature. During the incubation period, the soil samples were shaken twice a day, each was 30 minutes. At the end of incubation, soil samples were centrifuged and the solution was filtered and stored in the bottles. To study the desorption of P, soils in centrifuge tubes after P sorption experiment (after the supernatant solution separated) was shaken with 28 ml of 0.01 mol L^{-1} $CaCl_2$ with an incubation period equal to P sorption experiment. The concentration of P in solution of P sorption and desorption experiment were determined by the method of Murphy and Riley (1962). The absorbance at 660 nm was determined using a UV spectrophotometer. Data were simulated with Langmuir Equation in a linear form:

$$C/x/m = 1/kb + C/b$$

where C is the concentration of phosphorus in the equilibrium level (mg L^{-1}), x / m is the P sorbed per weight of soil (mg kg^{-1}), k is a constant of bonding energy (L mg^{-1}), and b is the P sorbed maximum (mg kg^{-1}). In this research, it was used Completely Randomized Design (CRD) with two replications. Tukey test was used to further evaluate the treatments effect.

RESULTS AND DISCUSSION

P sorption

Figure 1 are curves showing P sorption on Rhodic Eutrudox without treatment (control), treatment of humic substances from Andisol and humic substances from peat soil. Figure 1 showed that P sorption curve of Rhodic Eutrudox treated with humic substances from peat soil was above that of control and that of treated with humic substances from Andisol. Figure 2 are curves showing P sorption on Typic Paleudult without treatment (control), treatment of humic substances from Andisol, and humic substances from peat soil. Figure 2 showed similar results with Figure 1.

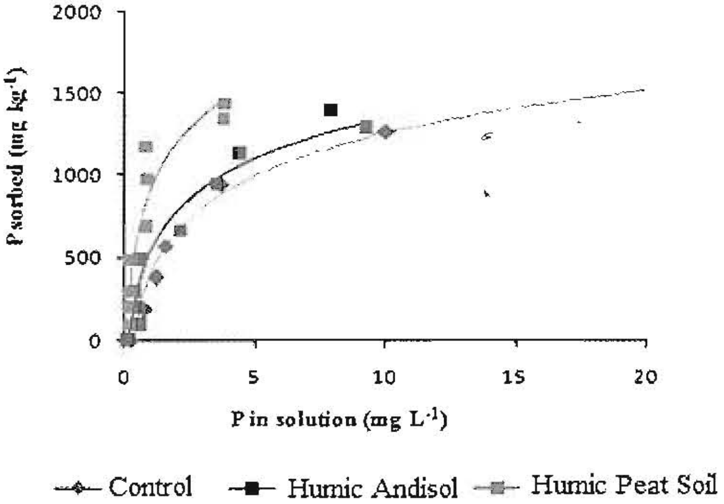

Fig. 1. P sorption Curve on Rhodic Eutrudox with application of humic substances from Andisol and peat soil

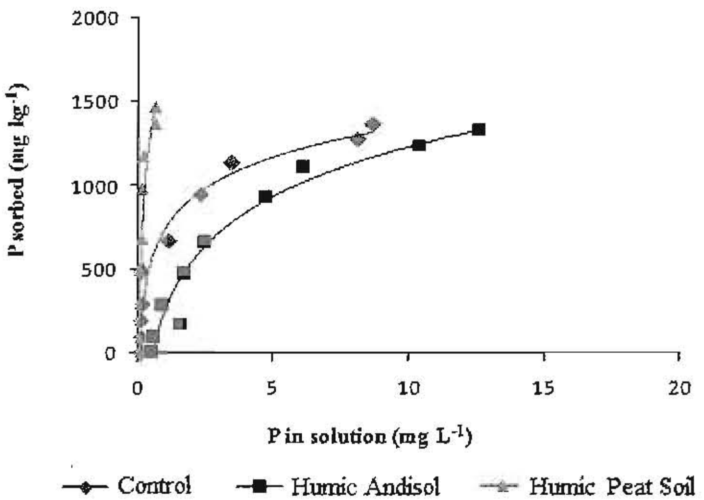

Fig. 2. P sorption Curve on Typic Paleudult with application of humic substances from Andisol and peat Soil

Langmuir sorption maxima (b), bonding energies (k), P standard requirements, and R^2 of Langmuir equation are presented in Table 2. P sorption data were very well simulated by the Langmuir equation. The regression coefficients values were 0.99. Treatments of humic substances from Andisol and humic substances from soil Peat were not consistent in affecting the P sorption maximum of the soils. Treatments of humic substances from Andisol and peat soil significantly decreased the P sorption maximum on Typic Rhodic Eutrodox but on the contrary the treatments increased the P sorption maximum on Typic Paleudult although statistically the increase of P sorption maximum were not significantly different. Similar with P sorption maximum, the effect of humic substances from Andisol or peat soil to the P bonding energies of the soils were not consistent. The humic substances from Andisol and peat soil increased the P bonding energies of Rhodic Eutrodox. The humic substances from Andisol decreased P bonding energy of Typic Paleudult but humic substances from peat soil increased the P bonding energy.

The difference results showed by the treatment of humic substance from Andisol and that of humic substance from peat soil was supposed by the differences in the formation of humic substance between Andisol and Peat soil. Arsiati (2002) reported that the COOH group at Peat soil were more than the Andisol.

The mechanisms concerning the binding of P by COOH group were illustrated by Tan (1998). Figure 3 showed that P can be bonded directly by ligand exchange between OH^- and PO_4^- or by coadsorption using metal bridging.

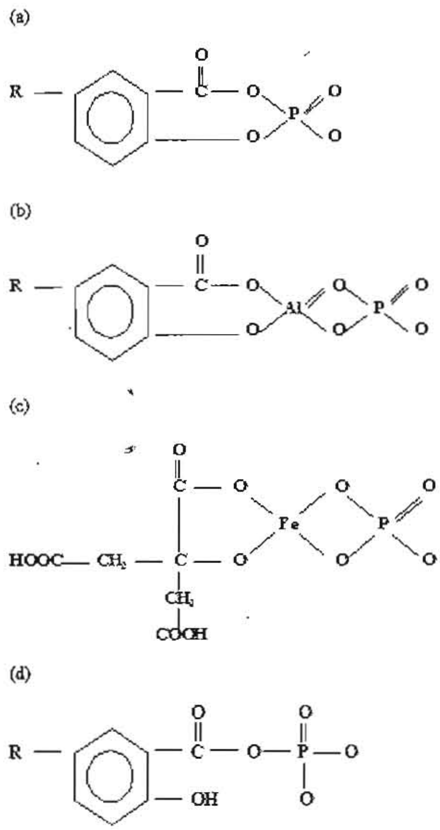

Fig. 3. The binding of P by humic acid or coadsorption with Al and Fe (a) Phospho-humic acid chelate, (b) Al-phosphohumate, (c) Fe-Phosphocitrate, (d) Fosfo-humic acid ester (Tan, 1998).

Standard P requirements or P sorbed at 0.2 mg L^{-1} are presented in Table 2. It is showed that in Rhodic Eutrodox both humic substances increased standard P requirements. However in Typic Palendult humic substances from Andisol decreased significantly standard P requirements. These results correlated with their P bonding energies.

Table 2. Equilibrium Langmuir sorption maxima (b), bonding energies (k), standard P requirements of the soils and r values

Treatments	Rhodic Eutrudox				Typic Paleudult			
	b	k	P sorbed at 0.2 mg L^1	R^2 of Linear Equatiou	b	k	P sorbed at 0.2 mg L^1	R^2 of Linear Equation
	mg kg^{-1}	L mg^{-1}	mg kg^{-1}		mg kg^{-1}	L mg^{-1}	mg kg^{-1}	
Control	2109 a	0.18 a	73 a	0.99	1432 a	1.27 a	289 a	0.99
Humic Andisol	1683 b	0.41 b	128 b	0.99	1821 a	0.22 b	75 b	0.99
Humic Peat Soil	1712 b	1.10 c	309 c	0.99	1769 a	6.42 c	995 c	0.99

Means followed by the same letter within a column are not significantly different (Tukey's test, $P < 0.05$)

P Desorption

P desorption curves of Rhodic Eutrodox and Typic Paledult are presented in Figure 4 and 5 respectively. They showed that P sorbed from soils treated with humic substances from peat soil were very difficult to desorp, while P sorbed from soils treated with humic substances from Andisol were similar with control soils.

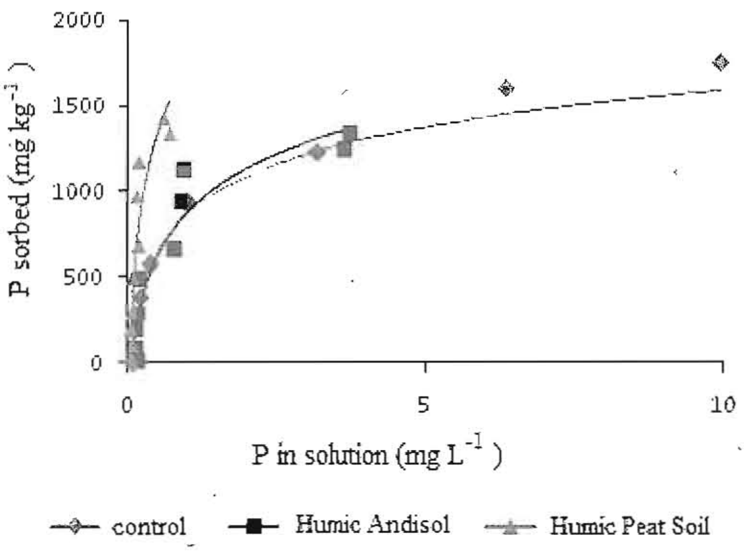

Fig. 4. P desorption curves of Rhodic Eutrudox

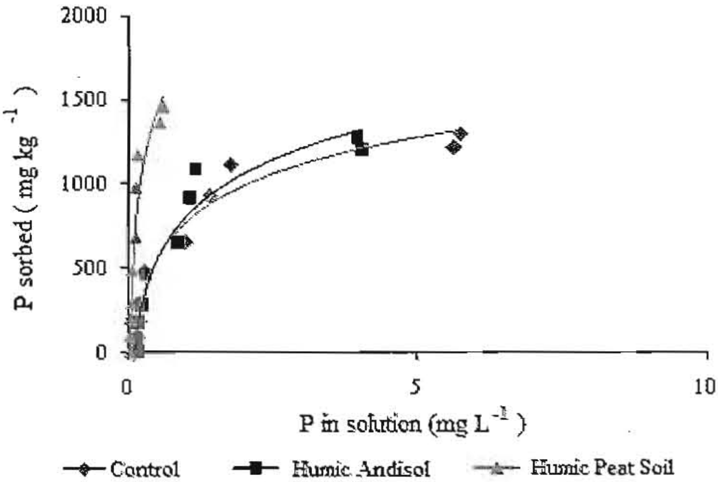

Fig. 5. P desorption curves of Typic Paleudult

Their P sorption maxima and bonding energies are presented in Table 3. Table 3 showed that the significant changes in desorption experiment was their P bonding energies. Soils treated with humic substances from peat soil had P bonding energies significantly higher than those of control and soils treated with humic substances from Andisol. It suggested that P in soils treated with humic substances from peat soil were sorbed very strong. Soils treated with humic substances from Andisol desorbed more P than those of soils treated with humic substances from peat soil (Table 4)

Table 3. Equilibrium Langmuir sorption maxima (b), bonding energies (k) revealed from desorption experiment

Treatments	**Rhodic Eutrudox**		**Typic Paleudult**	
	b	**k**	**b**	**k**
	mg kg^{-1}	L mg^{-1}	mg kg^{-1}	L mg^{-1}
Control	1821 a	1.07 a	1440 a	1.27 a
Humic Andisol	1552 a	1.34 a	1552 a	1.04 a
Humic Peat Soil	1751 a	5.71 b	1700 a	8.91 b

Means followed by the same letter within a column are not significantly different (Tukey's test, $P < 0.05$)

Table 4. Percentage of P desorbed

Treatments		**P added**	**P sorbed**	**P desorbed**	**Percentage of P desorbed**
		....	mg kg^{-1}	....	%
Rhodic Eutrudox	Control	1382	1263 a	35.20 a	2.79 a
	Humic Andisol	1382	1281 a	40.56 a	3.17 a
	Humic Peat Soil	1382	1337 b	7.56 b	0.57 b
Typic Paleudult	Control	1372	1281 a	61.68 a	4.81 a
	Humic Andisol	1372	1241 b	44.44 b	3.57 b
	Humic Peat Soil	1372	1364 c	5.76 c	0.42 c

Means followed by the same letter within a column are not significantly different (Tukey's test, $P < 0.05$)

CONCLUSIONS

The application of humic subtances did not consistently decrease or increase P sorption maxima and bonding energies of the soil with high amount of Al and Fe oxide in P sorption experiment. Humic substances from peat soil resulted in the highest increase of P bonding energies of the soils.

The application of humic substances from Andisol was better than that of peat soil in terms of the degree of P desorbed of the soils. It was suggested that the different effects of humic substances from Andisol and Peat Soils are due to the different composition of humic substances.

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