Correlation between Soil Test Phosphorus of Kaolinitic and Smectitic Soils with Phosphorus Uptake of Lowland Rice

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ABSTRACT

Correlation between Soil Test Phosphorus of Kaolinitic and Smectitic Soils with Phosphorus Uptake of Lowland Rice (M. Masjkur): Correlation between soil test phosphorus (P) and plant-available P parameters were affected by soil properties, such as soil pH, particle-size composition, and mineralogy. The objectives of this research were: (1) to determine P concentration extracted by several soil P test method in kaolinitic and smectitic soil, and (2) to determine correlation between soil P test and soil properties, P fractions, P sorption parameters, and P uptake of lowland rice. The soil P test in kaolinitic and smectitic soil used solutions of HCl 25%, Truog, Olsen, Bray1, Mehlich1, and Morgan Venema and were correlated with P uptake of lowland rice in field experiment. Concentration of Truog-P in kaolinitic soil was significantly higher than smectitic soil, while concentration of Morgan-P in kaolinitic soil was significantly lower than smectitic soil. Concentration differences of HCl 25%-P, Olsen-P, Bray1-P, and Mehlich1-P between kaolinitic and smectitic soil were not significant. In kaolinitic soil correlation between HCl 25%-P, Olsen-P, Bray1-P, and Mehlich1-P, and Morgan-P with P uptake of lowland rice were not significant. In smectitic soil HCl 25%-P, Olsen-P, Bray1-P, and Mehlich1-P correlated significantly with P uptake of lowland rice, while Morgan-P was not significant.

Keywords: Kaolinitic, lowland rice, smectitic soil, P test

INTRODUCTION

Soil P test is a useful diagnostic tool to predict P availability for plants. Soil P test measures the capacity of P supply from soil and estimate part of total reserves of soil P. Soil test values obtained will be less useful, unless calibrated with crop response to P fertilization in the field (De Datta *et al.*, 1990; Mallarino and Atia , 2005).

The correlation between soil P test with phosphorus availability parameters for crops were affected by soil properties, including soil pH, particle size composition, and mineralogy, and few generalizations are possible between different soils (Teo *et al.*, 1995; Mariano *et al.*, 2002; Mallarino and Atia, 2005).

Soil P test research on paddy rice conducted by Soil Research Institute showed that there were some soil test methods can be used to determine levels of P in paddy field and correlated positively with rice yield. The levels of soil P determination can use methods such as Olsen, Bray1, Mehlich1, Morgan Wolf, and HCl 25% depending on the type of soil. The HCl 25% solution in general can be used to determine the P nutrient content of ricesoil (Rochayati and Adiningsih, 2002).

The purposes of these study are: (1) to know the level of P extracted with several soil P test methods in kaolinitic and smectitic soils, and (2) knowing soil P test correlation with soil properties, P forms, P sorption parameters, and P uptake rice paddies.

MATERIALS AND METHODS

Field research was conducted at three locations Ultisol kaolinitic wetland in Lampung that are Purworejo1 (low P), Purworejo2 (medium P), and Simbarwaringin (very high P) and three locations Vertisol smectitic rice field in East Java that are Demangan (medium P), Kedungrejo (high P) and

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Tirtobinangun (very high P) in the 2005/2006 planting season. Laboratory research was conducted in Research Laboratory of Soil Research Institute Bogor.

The soil samples (0-20 cm top layer) were taken from the field trial locations. Soil samples airdried, crushed and sieved with a 2 mm sieve. Soil properties analyses include : pH (H_2O), clay content, organic C, exchangeable Ca (NH_4OAc 1 M pH 7), exchangeable Fe (DTPA), exchangeable Al (KCl 1 N), P fractions (Sui *et al.*, 1999), and P sorption parameters (Fox and Kamprath, 1970).

Soil P test in kaolinitic and smectitic soil use solutions : (1) HCl 25% (7.7*N* HCl), (2) Truog (0.002*N* H_2SO_4 + 0.023*N* $(NH_4)_2SO_4$), (3) Olsen (0.5*M* $NaHCO_3$ pH 8.5), (4) Bray-1 (0.025*N* HCl + 0.03*N* NH_4F), (5) Mehlich-1 (0.05*N* HCl + 0.025*N* H_2SO_4), and (6) Morgan Venema (1*N* NH_4-Acetate pH 4.8) (Fixen and Grove, 1990).

The difference of soil P test concentration between kaolinitic and smectitic soils with the same prior HCl 25%-P content analysed with *two samples t-test* (Montgomery, 2001). Correlation between soil P test with P forms, P sorption parameters, soil properties and P uptake in the kaolinitic and smectitic soil analyzed with Pearson correlation test.

RESULTS AND DISCUSSION

Soil P Test on Kaolinitic and Smectitic Soil

The P levels extracted with six methods soil P test on kaolinitic and smectitic soil can be seen in Table 1.

The P concentration extracted with HCl 25%, Bray-1, and Mehlich-1 tests on the kaolinitic soil lower than smectitic soil, but not significantly different at $\alpha = 0.05$ (Table 1). The difference HCl 25 % test probably because positive correlation HCl 25% test with $NaHCO_3$-P_i, $NaHCO_3$-P_o, Res-P and sorption maximum parameter (0.77 **, 0.51*, 0.71 ** and 0.93 ** respectively) (Table 2). Increasing soil $NaHCO_3$-P_i, $NaHCO_3$-P_o, Res-P and sorption maximum parameter could have increased the HCl 25% test.

The difference Bray-1-P test between kaolinitic and smectitic soil probably because significant positive correlation Bray1-P with $NaHCO_3$-P_i and $NaHCO_3$-P_o (0.73 and ** 0.51 * respectively) (Table 2). Increasing soil $NaHCO_3$-P_i and $NaHCO_3$-P_o , could have increased the soil Bray1-P test. The significant negative correlation Bray-1-P test with organic C (-0.55 *) (Table 2) suggests that the Bray-1 P test does not extract a stable organic P (organic P in humic material) or organic C may neutralize the acid in the solution extractant and / or the formation of organo-fluoride complex. The anions of organic acids can bind H^+ (Haynes and Mokolobate, 2001).

The difference Mehlich-1 test probably because Mehlich-1 test positively correlated with $NaHCO_3$-P_i, $NaHCO_3$-P_o, and HCl-P (0.81 **, 0.69 ** and 0.64 ** respectively) (Table 2). Increasing soil $NaHCO_3$-P_i, $NaHCO_3$-P_o, and HCl-P could have increased the Mehlich-1 P test.

The concentration of Olsen P test on kaolinitic soil was higher than smectitic soil, but not significantly different at $\alpha = 0.05$ (Table 1). The difference Olsen P test probably because Olsen P test positively correlated with $NaHCO_3$-P_i and $NaHCO_3$-P_o (0.94 ** and 0.63 ** respectively) (Table 2).

Table 1. Phosphorus concentration of soil test P for rice on kaolinitic and smectitic soil.

Location	HCl-25	Truog	Olsen	Bray-1	Mehlich-1	Morgan
	---------- mg kg^{-1} P_2O_5 ----------					
Purworejo 1	129.75 a	58.00 a	24.25 a	21.75 a	9.00 a	2.00 a
Purworejo 2	246.00 b	97.75 b	45.00 b	27.50 b	12.50 b	3.50 b
Simbarwaringin	759.50 c	77.75 c	41.50 b	7.25 c	7.00 a	1.75 a
Demangan	275.00 a	36.47 a	5.50 a	2.37 a	3.75 a	3.55 a
Kedungrejo	532.50 b	42.32 a	36.25 b	6.02 a	10.77 b	3.75 a
Tirtobinangun	747.50 c	76.15 b	73.00 c	37.00 b	22.82 c	5.30 a
Kaolinitic	502.75 a	87.75 a	43.25 a	17.37 a	9.75 a	2.62 a
Smectitic	511.25 a	56.31 b	39.25 a	19.69 a	13.29 a	4.42 b

Means with the same letter are not significant at $\alpha = 0.05$.

Table 2. Correlation between soil test P, soil properties, P fractions, and P sorption parameter on kaolinitic and smectitic soil.

Soil properties	Soil P test					
	HCl25-P	Truog-P	Olsen-P	Bray1-P	Mehlich1-P	Morgan-P
pH	0.05	-0.61*	-0.01	0.15	0.31	0.65**
Clay	-0.04	-0.80**	-0.29	-0.18	0.01	0.42
Organic C	-0.37	-0.66**	-0.65**	-0.55*	-0.49	-0.08
Ca	-0.01	-0.64**	-0.08	0.09	0.25	0.65**
Fe	-0.23	0.61*	-0.04	-0.11	-0.31	-0.59*
Al	0.17	0.55*	0.05	-0.21	-0.30	-0.65**
H_2O-P	0.16	-0.64**	0.01	0.09	0.30	0.54*
NaC-P_i	0.77**	0.56*	0.94**	0.73**	0.81**	0.29
NaC-P_o	0.51*	0.23	0.63**	0.51*	0.69**	0.50*
NaO-P_i	-0.28	0.43	-0.20	-0.22	-0.40	-0.52*
NaO-P_o	0.34	-0.49	0.01	-0.05	0.12	0.09
HCl-P	0.36	-0.31	0.39	0.44	0.64**	0.73**
Res-P	0.71**	-0.17	-0.03	-0.49	-0.29	-0.52*
Tot-P	0.88	-0.17	0.24	-0.21	0.06	-0.21
b	0.93**	-0.15	0.36	-0.05	0.21	-0.06
k	-0.28	0.69**	0.04	0.03	-0.20	-0.48
bk	0.05	0.58*	0.02	-0.20	-0.33	-0.70**

* = significant at α = 0.05; **= significant at α = 0.01; P=phosphorus; P_i =inorganic P; P_o=organic P; NaC= $NaHCO_3$; NaO = NaOH; Res = residual; Tot = total; b=sorption maximum parameter; k = bonding energy; bk = buffer capacity.

Increasing soil $NaHCO_3$-P_i and $NaHCO_3$-P_o could have increased the soil Olsen P test. According to result Stevenson and Cole (1999) that high pH of Olsen P test dissolved labile organic P. The significant negative correlation between Olsen P test with organic C (-0.65 **) (Table 2) indicate that Olsen P test does not extract a stable organic P (organic P in humic substances).

The concentration of Truog-P test on kaolinitic soil was significantly higher than smectitic soil (Table 1). This result probably because Truog-P test positively correlated with exchangeable Al (0,55 *) and exchangeable Fe (0.61 *) (Table 2). The result indicate that sulfuric acid and a solution of $(NH_4)_2SO_4$ on the Truog-P test (0.002*N* H_2SO_4 + 0.023*N* $(NH_4)_2SO_4$) efficiently dissolve the soil Al-P and Fe-P. Increasing soil exchangeable Al and Fe could have increased the soil Truog P test. According to result Havlin *et al*. (1999) that acid soil generally have higher soil Fe and Al content than calcareous or alkaline soil.

In addition, the Truog-P test also efficiently dissolve labile inorganic P ($NaHCO_3$-P_i) as shown by significantly positive correlation Truog-P test with $NaHCO_3$-P_i (0.56 *) (Table 2). Increasing soil $NaHCO_3$-P_i could have increased the soil Truog P test. The negative correlation Truog-P test with organic C (-0.66 **) indicates that Truog test does not dissolve organic P of humic material.

The Truog-P test positively correlated with buffer capacity and bonding energy parameter (0.58 * and 0.69 ** each) (Table 2). These results indicate that increasing soil buffer capacity and bonding energy parameter could have increased Truog-P test.

Data in Table 1 show that concentration of Morgan-P test on kaolinitic soil was significantly lower than smectitic soil. The difference apparently due to positive correlation Morgan tests with the soil pH (0.65 **) and exchangeable Ca (0.65 **) (Table 2). These results indicate that the NH_4-acetate buffered at pH 4.8 in Morgan test efficiently dissolve Ca-P that commonly found in high pH soil. Increasing soil pH and exchangeable Ca could have increased the soil Morgan P test. According to finding Havlin *et al.* (1999) that Ca-P was dominant on calcareous or alkaline soil. The negative correlation Morgan test with exchangeable Al (-0.65 **) and exchangeable Fe (-0.59 *) indicates that Morgan test was not efficient to dissolve soil Fe-P and Al-P.

The Morgan tests positively correlated with the soil $NaHCO_3$-P_o (0.50 *) and HCl-P (0.73 **), but negatively correlated with the residual-P (-0.52 *) (Table 2). These results indicate that Morgan test effectively dissolved labile organic P and moderately

Table 3. Correlation between soil test P and rice P uptake on kaolinitic soil.

Soil P test	HCl25-P	Truog-P	Olsen-P	Bray1-P	Mehlich1-P	Morgan-P
Truog-P	0.17	-	-	-	-	-
Olsen-P	0.49	0.88**	-	-	-	-
Bray1-P	-0.83**	0.31	-0.01	-	-	-
Mehlich1-P	-0.52	0.66*	0.43	0.86**	-	-
Morgan-P	-0.39.	0.75**	0.52	0.71**	0.82**	-
P Uptake	-0.13	-0.74**	-0.63*	-0.16	-0.38	-0.59*

* = significant at α = 0.05; **= significant at α = 0.01.

stable Ca-P, but less effectively dissolve stable Ca-P and organic P. Increasing soil $NaHCO_3$-P_o and HCl-P could have increased the soil Morgan P test.

Correlation between Rice P Uptake and Soil P Test on Kaolinitic and Smectitic Soil

In kaolinitic soil, HCl 25% test negatively correlated with the Bray1-P test (-0.83 **) (Table 3). This result indicates that HCl 25% test extract different pool-P with Bray-1 P test. The Truog P test positively correlated with Olsen P (0.88 **), Mehlich-1 P (0.66 *), and Morgan P tests (0.75 **). The Bray-1 P test positively correlated with Mehlich-1 P (0.86 **) and Morgan test (0.71 **), whereas Mehlich-1 P test positively correlated with the Morgan test (0.82 **) (Table 3). Agree with finding Magdoff *et al*. (1999) that the Bray-1 P test positively correlated with the Morgan test. The positive correlation between soil P test methods indicate that the soil P test methods extract relatively the same P-pool and P-intensity.

Data in Table 3 show that the HCl 25%-P, Bray1-P and Mehlich1-P tests were not significantly correlated with P uptake of rice paddy (-0.13^{ns}, -0.16^{ns}, and -0.38^{ns} each), while Truog-P, Olsen-P and Morgan-P tests were negatively correlated (-0.75 **, -0.64 * and -0.59 * each) (Table 3). These results indicate that the HCl 25%-P, Truog-P, Olsen-P, Bray-1-P, Mehlich-1-P, and Morgan-P were less reliable as the parameters of plant-avalaible P for rice paddy on the kaolinitic soil. These facts may be caused by the relatively high bonding energy of P in kaolinitic soil.

Therefore, further research needed to test another soil test P extractant reliable as parameter of plant-avalaible P for rice paddy on the kaolinitic soil such as Bray-2, Mehlich-3, water soluble-P, or anion exchange resin-P. According to result Fixen and Grove (1990) that Bray-2 solution (0.03*M* NH_4F + 0.1*M* HCl) has stronger acid concentration compared with Bray-1 solution. Teo *et al*. (1995) argued that the Mehlich-3 P test (combination 0.015*M* NH_4F, 0.2*M* CH_3COOH, 0.25*M* NH_4NO_3, and 0.013*M* HNO_3) was quite reliable and an alternative test of P in paddy field. Sharpley *et al*. (2004) suggests that water soluble-P correlated closely with the Mehlich-3 P test (0.97 **). This research found that in kaolinitic soil H_2O-P fraction positively correlated with rice paddy P uptake (0.68*). Mariano *et al*. (2002) found that the resin-P test was reliable and efficient as a parameter of paddy-available P in acid soil.

In smectitic soil HCl 25% P test positively correlated with Truog (0.82 **), Olsen (0.99 **),

Table 4. Correlation between soil test P and rice P uptake on smectitic soil.

Soil P test	HCl25-P	Truog-P	Olsen-P	Bray1-P	Mehlich1-P	Morgan-P
Truog-P	0.82**	-	-	-	-	-
Olsen-P	0.99**	0.83**	-	-	-	-
Bray1-P	0.88**	0.91**	0.92**	-	-	-
Mehlich1-P	0.93**	0.95**	0.94**	0.92**	-	-
Morgan-P	0.37	0.70*	0.36	0.37	0.60*	-
P Uptake	0.95**	0.73**	0.92**	0.72**	0.88**	0.40

* = significant at α = 0.05; **= significant at α = 0.01.

Bray-1 (0.88 **) and Mehlich-1 P tests (0.93 **) (Table 4). The Truog-P test positively correlated with Olsen (0.83 **), Bray-1 (0.91 **), Mehlich-1 (0.95 **), and Morgan P tests (0.70 *). Olsen P test positively correlated with the Bray-1 (0.92 * *) and Mehlich-1 P tests (0.94 **), whereas Bray-1 P test positively correlated with the Mehlich-1 P test (0.92 **). The Mehlich-1 P test positively correlated with the Morgan P test (0.60 *). Havlin *et al*. (1999) showed that the Olsen P test is closely correlated with Bray-1 P test on the calcareous soils. Mallarino and Atia (2005) also found that the Olsen P test positively correlated with the Bray-1 P test (r = 0.94 **). The positive correlation between P test methods indicate that the P test methods extract relatively the same pool of P and these P test methods may be interchangeable (Magdoff *et al*., 1999; Mallarino and Atia, 2005).

The HCl 25%, Truog, Olsen, Bray-1 and Mehlich-1 P tests positively correlated with rice paddy P uptake in smectitic soil (0.95 **, 0.73 **, 0.92 **, 0.73 ** and 0.88 ** respectively), while the Morgan P test was not significantly correlated (0.40^{ns}) (Table 4). These results indicate that the HCl 25%, Truog, Olsen, Bray-1 and Mehlich-1 P tests were reliable as the parameters for rice paddy-available P in smectitic soil, while the Morgan P test was less reliable. Thus P fertilizer recommendation on smectitic soil can use the HCl 25%, Truog, Olsen, Bray-1 and Mehlich-1 P tests.

CONCLUSIONS

The phosphorus concentration of Truog P test on kaolinitic soil was higher than smectitic soil, while concentration of the Morgan P test on kaolinitic soil was lower than smectitic soil. The P concentration of the HCl 25%, Olsen, Bray-1, and Mehlich-1 P tests on kaolinitic and smectitic soil were relatively similar.

In kaolinitic soil HCl 25%, Truog, Olsen, Bray-1, Mehlich-1, and Morgan P tests were less reliable as the parameters of P availability for rice paddies. In smectitic soil the HCl 25%, Truog, Olsen, Bray-1 and Mehlich-1 P tests were reliable as the parameters plant-available P for rice paddy fields, while the Morgan test is less reliable.

Further research needed to investigate another soil P tests reliable on kaolinitic and smectitic soil, including Bray-2, Mehlich-3, water soluble-P or anion exchange resin-P.

REFERENCES

De Datta, S. K., T. K. Biswas, and C. Charoen-chamratcheep. 1990. Phosphorus Requirements and Management for Lowland Rice. Proceedings of Symposium Phosphorus Requirements for Sustainable Agriculture in Asia and Oceania. International Rice Research Institute, Los Banos, Laguna, Philippines, pp. 307-323.

Fixen, P. E. and J. H. Grove. 1990. Testing Soils for Phosphorus. In: Westerman (Ed.) Soil Testing and Plant Analysis. Soil Sci. Soc. Am., Madison, WI, pp. 141-180.

Fox, R. L., and E. J. Kamprath. 1970. Phosphate Sorption Isoterms for Evaluating the Phosphate Requirements of Soils. Soil Sci. Soc. Am. Proc. 34: 902-907.

Havlin, J.L., J.D.Beaton, S.L. Tisdale, and W.L. Nelson. 1999. Soil Fertility and Fertilizers. An Introduction to Nutrient Management. Prentice-Hall, New Jersey.

Haynes, R. J., and M. S. Mokolobate. 2001. Amelioration of Al Toxicity and P Deficiency in Acid Soils by Additions of Organic Residues: A Critical Review of Phenomenon and the Mechanisms Involved. Nutr. Cycl. Agr. 59: 47-63.

Magdoff, F. R., C. Hryshko, W. E. Jokela, R. P. Durieux, and Y. Bu. 1999. Comparison of Phosphorus Soil Test Extractants for Plant Availability and Environmental Assesment. Soil Sci. Am. J. 63: 999-1006.

Mallarino, A. P., and A. M. Atia. 2005. Correlation of a Resin Membrane Soil Phosphorus Test with Corn Yield and Routine Soil Tests. Soil Sci. Am. J. 69: 266-272.

Mariano, I. O. dos Santos, L. A. Fernandes, V. Faquin, and A. T. de Andrade. 2002. Phosphorus Critical Levels and Availability in Lowland Soils Cultivated with Flooded Rice. Scientia Agricola 59: 1-12.

Rochayati, S. and J. S. Adiningsih. 2002. Pembinaan dan Pengembangan Program Uji Tanah untuk Hara P dan K pada Lahan Sawah. Dalam: Z. Zaini, A. Sofyan, dan S. Kartaatmadja (Eds.) Pengelolaan Hara P dan K pada Padi Sawah. Pusat Penelitian Tanah dan Agroklimat, Bogor, Hlm. 9-37.

Sharpley, A. N., R. W. McDowell, and P. J. A. Kleinman. 2004. Amounts, Forms, and Solubility of Phosphorus in Soils Receiving Manure. Soil Sci. Soc. Am. J. 68: 2048-2057.

Stevenson, F. J., and M. A. Cole. 1999. Cycles of Soil. John Wiley and Sons, New York.

Sui, Y., M. L. Thompson, and C. Shang. 1999. Fractionation of Phosphorus in a Mollisol Amended with Biosolids. Soil Sci. Soc. Am. J. 63: 1174-1180.

Teo, Y. H., C. A. Beyrouty, and E. E. Gbur. 1995. Relating Soil Test P to P Uptake by Paddy Rice. Soil Sci. 159: 409-414.