

EFFECT OF P AND SI AMENDMENT ON THE CHARGE CHARACTERISTICS AND MANAGEMENT OF A GERIC SOIL

Chon Quang Nguyen, Chris Guppy and Phil Moody

INTRODUCTION

In Vietnam, upland soils such as Acrisols and Ferralsols cover about 72 percent of the total surface (Nguyen and Thai, 1999; Ton *et al.*, 1996). These highly weathered tropical soils are characterised by high desilication, soil acidity and phosphorus fixation and are intensively cultivated with minimal fertiliser input (Nguyen and Thai, 1999). Soil surface charge is often characterised by net positive charge, a geric property, especially in the subsoil layer of Ferralsols (Moody and Phan, 2008). Therefore, cations are easily leached and soil fertility conditions deteriorate. Theoretically, cation loss can be prevented by developing negative surface charge and thus creating additional cation exchange capacity (CEC) (Uehara and Gillman, 1981). This can be obtained either by raising soil pH, increasing the electrolyte concentration in the soil solution or lowering the pH_0 . Soil amendments that may affect these soil properties include lime, phosphate, silicate and organic matter application. This paper presents the effect of P and Si amendment application on the charge characteristics of a Ferrosol from north Queensland having similar charge characteristics to Ferralsols in the uplands of Vietnam.

MATERIALS AND METHODS

Soil was collected at a depth of 20-40cm (to remove interference from organic matter in determining charge characteristics) from a Pingin series Red Ferrosol under sugarcane cultivation in north Queensland. The sample was air-dried and passed through a 2mm-sieve before incubation and analysis. Soil properties and soil charge characteristics are presented in Table 1.

Table 1. Soil and soil charge properties of a Pingin subsoil (20-40cm)

Si (%)	Si salt ext. ¹ (μM)	P sorbed ² (mg kg^{-1})	Soil pH ³	pH_0	CEC_B ⁴	CEC_T ⁵	AEC ⁶	PZNC ⁷
					(cmol _c kg ⁻¹)			
6.48	78	985	4.27	4.67	0.22	0.24	0.62	4.79

¹ 0.01M CaCl₂ (1:1000 ratio of soil:solution); ² P sorbed from added 1000 mg P kg⁻¹; ³ Soil pH in 0.002 M CaCl₂ (1:10 ratio of soil:solution); ⁴ CEC_B – Base cation exchange capacity; ⁵ CEC_T – Total cation exchange capacity; ⁶ AEC – Anion exchange capacity; ⁷ PZNC – Point of zero net charge

A 100 g soil sample with 20% moisture content was incubated in a pot placed in the oven at 40°C. Water was added daily to maintain moisture content at 20%. Eight treatments were involved in this study. Fused magnesium phosphate (FMP) was applied at the rates of 0, 75, 150 and 300 mg P kg⁻¹. The silicate materials, wollastonite (Ca-Si) and olivine (Mg-Si), were added at rates equal to the Si content in FMP at 300 mg P kg⁻¹, i.e. 320 mg Si kg⁻¹. Acidulated wollastonite (Ac-Ca-Si) and acidulated olivine (Ac-Mg-Si) were added to be equivalent in applied Si to that of the 150 mg P kg⁻¹ application of FMP, i.e. 160 mg Si kg⁻¹. Chemical components of amendments are presented in Table 2.

After seven days of incubation, soils were analysed for pH, pH₀, CEC_B, CEC_T, AEC and PZNC by using the charge fingerprint procedure (Gillman, 2007); Colwell extractable P (Colwell, 1963) and phosphorus buffering index (PBI) (Burkitt *et al.*, 2002) were also determined.

Table 2. Chemical components of amendments

Amendments	P (%)	Si (%)	¹ Si salt extractable (μM)	Neutralising value (%)
FMP	7.11	7.47	139	47.7
Ca-Si	-	25.65	167	48.1
Ac-Ca-Si	-	20.00	nd	0
Mg-Si	-	11.02	103	53.3
Ac-Ca-Si	-	7.23	525	0

¹ 0.01M CaCl₂ (1:1000 ratio of soil:solution)

RESULTS

After seven days of incubation at 40⁰C, soil pH increased with increasing levels of applied FMP, about one unit pH increment after treatment with 300 mg P kg⁻¹(Figure 1). FMP applications also shifted pH₀ to lower values than that of the control; the more P applied, the lower the values of pH₀.

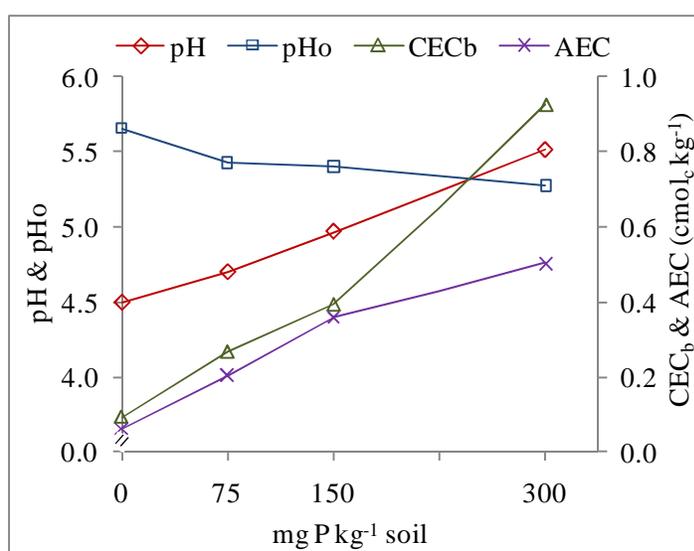


Figure 1. Change in soil pH and charge characteristics of a Pingin series subsoil as a function of P application as FMP following incubation for 7 days at 40⁰C and near field capacity

Phosphorus affected both CEC and AEC of the soil, the higher P application, the greater the increase in CEC and AEC (Figure 1). However, the increase in AEC was smaller than CEC following application of 300 mg P kg⁻¹.

Where the soil was treated with unacidulated silicate amendments (Ca-Si and Mg-Si), soil pH increased and pH₀ decreased (Table 3). In contrast, PZNC was higher in silicate treated soils compared to the control, except the soil with Ac-Mg-Si. CEC and AEC also increased with silicate applications, but AEC decreased in the Ac-Ca-Si treatment. Similar to the effects with P application, silicate addition resulted in higher pH₀ and lower PZNC than those of the non-incubated baseline soil, but CEC and AEC of the soil treated with silicates were reduced in comparison to the non-incubated initial values. The exception was the Ac-Mg-Si treatment where both CEC_B and CEC_T were kept at the same values as the non-incubated baseline soil (Table 1 and 3).

Although Colwell P was not responsive to applied silicates, PBI decreased (Table 3). Hence soil P sorption capacity may be reduced by applying silicate.

Table 3. Effect of Si application on the charge characteristics, P availability and PBI of a Pingin series subsoil incubated for 7 days at 40°C near field capacity

Amendments	Si added (kg ha ⁻¹)	pH _(CaCl2) (1:10)	pH ₀	PZNC	CEC _B CEC _T AEC			P _{Colwell} (mg kg ⁻¹)	PBI
					(cmol _c kg ⁻¹)				
Control	0	4.49	5.63	4.28	0.09	0.11	0.06	33.5	838
Ca-Si	420	4.88	5.41	4.43	0.19	0.21	0.10	35.8	798
Ac-Ca-Si	210	4.54	5.41	4.35	0.11	0.14	0.01	33.1	812
Mg-Si	420	4.81	5.43	4.42	0.17	0.18	0.11	33.6	816
Ac-Mg-Si	210	4.61	5.32	4.14	0.21	0.23	0.11	31.5	784

DISCUSSION

The application of FMP and raw silicate materials (Ca-Si and Mg-Si) increased soil pH accounting for the majority of change in soil CEC_B (Figure 1; Table 3). Increased soil pH following application of phosphate or silicate ions to ferric soils is most likely associated with release of hydroxide ions following specific adsorption reactions (Smyth and Sanchez, 1980). Hence the most effective way to increase charge in geric soils is to increase soil pH rather than adjust pH₀. The exception to this trend occurred following application of Ac-Mg-Si where minimal change in pH was observed, yet CEC_B more than doubled (Table 3). The majority of the change in CEC_B for this amendment may be associated with lowering of the pH₀. The pH₀ of treated soils shifted to lower values compared to the control; this can be attributed to the specifically adsorbed anions HPO₄²⁻ and SiO₄²⁻ that are released from FMP and silicate amendments (Qafoku *et al.*, 2004; Uehara and Gillman, 1981; Zhang and Zhao, 1997). However, the pH₀ of all incubated soils, including the control, were higher than the pH₀ value of the non-incubated baseline soil. A number of factors may be involved with shift in pH₀ following incubation. First, the presence of Ca in the amended treatments may result in charge reversal due to Ca adsorption into the Stern layer (Uehara and Gillman, 1981). Second, organic carbon coating Fe and Al oxides might have oxidised/mineralised during incubation at 40°C, thus exposing surfaces with a relatively higher pH₀.

The interesting result of this study is that only the pH₀ value of FMP applied at 300 mg P kg⁻¹ was lower than soil pH. This might be caused by the dual effects of P and Si anions that were

released from FMP fertiliser. The relationship between soil pH and pH_0 determines the magnitude of net charge; therefore, the CEC in this treatment was greatly increased compared to the other treatments.

Among silicate sources, although Ac-Mg-Si did not increase soil pH as much as Ca-Si and Mg-Si, it was the most responsive amendment in terms of reducing pH_0 and increasing CEC_B of the soil. Also, Ac-Mg-Si did not increase Colwell P, but it decreased PBI to the lowest value compared to the other silicate sources (Table 3). These effects can be explained by more available Si being released to the soil from this product than the others, as salt extractable Si of Ac-Mg-Si was much higher than that in the other silicate amendments (Table 2).

CONCLUSIONS

The Pingin series subsoil has similar charge characteristics to those of the geric Ferralsols of the uplands of Vietnam in terms of very low CEC and high pH_0 . The application of FMP fertiliser not only overcomes a potential phosphorus deficiency, but through increasing pH may also increase soil charge and increase nutrient retention. Applying Ca-Si and Mg-Si materials can also rectify the problem of the geric property in highly weathered tropical soils by increasing the nutrient holding capacity of the soil and increasing P availability to the plant by the adsorptive competition of Si with P for sorption sites.