Dissolution of Eppawala phosphate rock in low country Ultisols as influenced by rate and method of application

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Abstract

The phosphorus (P) fertiliser requirement of tea is low (below 15 kg ha^{-1} yr^{-1}), despite high P fixing capacity of Ultisols in tea lands. Locally available, low cost, but sparingly soluble Eppawala Rock Phosphate (EPR) has been recommended as a source of P fertiliser for tea in Sri Lanka. However, no information is available on the changes of EPR in tea soils, under field conditions. The objective of this research was to study the effects of P rates *and method of application on EPR dissolution in an acid tea soil.*
The soil belongs to the Rhodustult (Red Yellow Podzolic soil – older Sri Lankan classification system) collected from a long–term phosphate fertiliser field trial started in 1993 located at field No.7, lower division of Walahanduwa Estate, in Galle. The trial comprised of annual application of P fertiliser treatments involving six rates i.e. 20, 40, 60, 80, 100 and 120 kg P_2O_5 ha^{-1}yr^{-1} and a control. P fertiliser was applied in the form of EPR in all treatments using two methods i.e. broadcasting on the soil surface and incorporation to a depth of 15-20 cm. Nitrogen and potassium fertilisers were applied at the rate equivalent of 240 kg N ha^{-1}yr^{-1} and 120 kg K_2O ha^{-1}yr^{-1} as Urea and Muriate of Potash, respectively. Treatments were arranged in a RCBD with three replicates.
Results showed that dissolution of EPR in soil was higher when applied to the soil surface by broadcasting than incorporation. In both methods, dissolved P was greater at lower rates of P application (20 kg P_2O_5) than higher rates. More than 50% of P in EPR was dissolved when broadcast, while release of P was relatively lower when incorporated. Therefore, surface application of EPR recommended for the tea lands is more preferred than that of incorporation.
Key words: Eppawala Phosphate Rock, Ultisols, Tea, P dissolution, Broadcasting, Incorporation

Introduction

The Phosphorus (P) nutrition of tea plants has received less attention in the past than nitrogen (N) nutrition. The response to applied phosphate fertilisers has been far less marked than response to N mainly because most P studies have been conducted on fertile soils or soils in which P fertilisers have been applied before (Zoysa, 2000). However, it is well known that in most tea soils frequently present problems limit tea production due to conditions associated with high soil acidity. Therefore, P availability in acid soils has become a subject of wider agricultural interest.

Tea soils are highly acidic (pH in water < 5.5) and tea growing areas receive considerably high rainfall (> 2000 mm yr^{-1}). Phosphate Rocks (PR) when applied to these soils are expected to dissolve and supply adequate amounts of P to plants (Zoysa *et al.* 1998). Therefore, direct application of finely ground, locally available PR, may be an economically attractive alternative to the use of more expensive imported soluble P fertilizers.

In mid 1970s, a large PR deposit estimated to be over 40 million metric tones (Jayawardana 1976) was discovered in Eppawala (North Central Province). PR is now recommended as a P fertiliser for direct application to several perennial crops including mature tea in Sri Lanka (Dahanayake *et al.* 1995).

However, published information on the chemical reactions and transformations of applied P fertilisers in tea soils under field conditions is scanty. Therefore, research was undertaken to study the optimum rate and effective method of application of Eppawala Phosphate Rock (EPR) dissolution in an acid tea soil.

Materialas and Methods

Soil analysis

The soil used belongs to Red Yellow Podzolic great soil group (De Alwis and Panabokke 1972) classified as Hapludults according to the US soil taxonomy (Soil Survey Staff 1996). Soil samples were collected from a long-term phosphate fertiliser field trial located at field No.7, Lower Division,

Walahanduwa Estate at Galle. The trial was started in 1994 and the field is grown with tea clone TRI 2025. Important physical and chemical characteristics of soil at the site are given in Table 2.1

Table 2.1 Physico-chemical characteristics of soil.

Soil characteristics	Unit	Value
Sand	%	64
Silt	%	16
Clay	%	20
Soil pH	water	4.76
	$CaCl_2$	4.12
Organic C	%	0.5
Total N	%	0.21
Borax-P	$\mu g\ g^{-1}$ soil	9.98
Resin-P	$\mu g\ g^{-1}$ soil	2.79
Bray and Kurtz-	$\mu g\ g^{-1}$ soil	1.94
P	$\mu g\ g^{-1}$ soil	83.3
Ex. K	$\mu g\ g^{-1}$ soil	137.5
Ex. Na	$\mu g\ g^{-1}$ soil	157
Ex. Ca	$\mu g\ g^{-1}$ soil	83.3
Ex. Mg	meq per 100 g soil	12.10
CEC		

Treatment and experimental design

There were six rates of P including 20, 40, 60, 80, 100, 120 kg P_2O_5 ha^{-1} yr^{-1} and a control. Different P fertiliser treatments were applied using two methods viz. broadcasting on the soil surface and soil incorporation to a depth of 15-20 cm. Each treatment was replicated thrice and treatments were arranged in a randomized completely block design. Each experimental plot consists of 38 to 42 tea bushes. Fertiliser treatments were applied to the experimental plots four times a year, leaving a three month interval. Nitrogen (N) and potassium (K) were applied to the plots at the rate of 360 and 180 kg ha^{-1} yr^{-1}, respectively.

Soil sampling

Representative soil samples were drawn randomly from 0 - 20 cm depth after removing the surface litter of plots. Soils were air-dried and crushed with a rubber tipped pestle and sieved through 2 mm mesh.

Chemical analysis

The amount of EPR dissolution in soil was determined according to the method of Tambunan et al. (1993). Exchangeable cations were extracted by 1 M NH_4Cl buffered at pH 7.0 (Blackmore *et al*. 1987). Soil Organic C was determined by the method of Walkley and Black (1934). Soil pH was measured using deionized water (10 g soil : 25 cm^3 water) and 0.01 $CaCl_2$ (10g soil : 25 cm^3 0.01 $CaCl_2$) using a pH meter.

Statistical analysis

The statistical analyses of data were performed using SAS programe (SAS 1987).

Results and Discussion

The concentration of undissolved-P recovered from P-dissolution was high in both methods of application for all treatments (Figure 1). The recovery of P increased with the rate of P applied to the soil. Repeated annual application of EPR for eight years resulted in an accumulation of considerable amount of EPR left in the soil undissolved. The accumulated EPR did not transformed in to other P-forms and remained as apatite P. It could be seen that the method of EPR application exerted a strong influence on the dissolution of EPR. When EPR was broadcast, the concentration of recovered EPR was lower, indicating that more EPR was dissolved. On the other hand, incorporation of EPR caused more recovery of EPR in the soil, indicating less dissolution in the soil.

Using results of undissolved P, the amount of dissolved-P (as P%) from applied EPR during eight years was estimated and results are shown in Figure 2. Dissolution of EPR was higher in all treatments when applied on the soil surface by broadcasting than incorporation to a depth of 15 - 20 cm. In both methods of application, amount of dissolved P being greater at lower levels of P (< 20 kg P ha^{-1} yr^{-1}) than at higher rates. More than 40% of applied P was dissolved in all the treatments. The possible reason is that at lower rates of EPR, there was proportionately higher acidity to enhance EPR dissolution and also more sinks for removal of dissolved products P, Ca, and F (Zoysa, 2000). Using glasshouse trials, Zoysa et al. (1999) reported that more than 50% of P from EPR was dissolved in the presence of tea plants in 10 months, at P rates below 20 kg P ha^{-1} in acid tea soils. Tambunan (1992) also observed in field trials on Ultisols of Indonesia under *Calopogonium*, the dissolution of NCPR (North Carolina Phosphate Rock) and MPR (Moroccan Phosphate Rock) added at the rate of 80 kg P ha^{-1} increased with the increase in contact period of PR and soil. For example, after 180, 360 and 545 days, dissolution of NCPR was 40, 82 and 98% respectively. EPR is a non-reactive phosphate rock and according to classification of PR based on their chemical reactivity (< 14% total P in EPR is soluble in 2% citric acid). Though EPR is sparingly soluble P fertiliser, high soil acidity (pH 4.5) and rainfall (> 2000 mm yr^{-1}) at the site enhanced dissolution of EPR considerably.

The amount of H^+ consumed for dissolving EPR in the soil was estimated using the amount of EPR dissolved and from the relationship that 2 moles of H^+ were consumed for every mole of P dissolved (%P in EPR/atomic weight of P/ 1/ 100/2 = 0.00933 μ mol H^+ μg^{-1} of EPR dissolved) (Table-1). Mineralogical analysis of EPR using XRD showed that EPR has no detectable amounts of free carbonates ($CaCO_3$ or $MgCO_3$) (Tazaki *et al.* 1987); therefore all acids consumed to be due to the reaction of acids with the apatite in EPR.

The H^+ consumption for the dissolution of EPR was lower for lower rates of P application in both methods of P fertilizer application. At higher rates of P application, H^+ consumption was higher. However, it was seen that less H^+ ions were required for the dissolution of EPR when incorporated than surface application. When EPR was incorporated to the soil, EPR gets concentrated as pockets or bands so that the dissolved products could not diffuse out of the reaction sites and accumulated around the particles. Therefore less acidity could penetrate in to the reaction site so that dissolution could not proceed. On the contrary, when EPR was applied to the soil surface, the dissolved products of EPR could move away from the reaction site along with percolating water and runoff etc. Hence more acidity could be expected for the dissolution of EPR with surface application.

Conclusion

The dissolution of EPR was higher when applied broadcast than incorporation to a depth of 15 – 30 cm. Therefore, deep placement of P in tea plantations cannot be considered as an agronomically feasible practice. In contrast, broadcasting of EPR is practically easy and economically viable due to the low cost of application.

Although EPR is considered as a non-reactive phosphate rock, more than 50% P in EPR was dissolved in the soil and the available acidity in soil was found to be sufficient for this purpose. The amounts of EPR dissolved were lower at higher rates and this could be due to the accumulation of dissolved products at the reaction site.

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