EFFECT OF AGROPASTORAL SYSTEMS ON MICROBIALLY BOUND PHOSPHORUS IN LOW P ACID SOILS

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ABSTRACT

The effect of agropastoral systems replacing native savanna on microbially bound phosphorus (P_{mic}) in low P acid soils was investigated. Chloroform released P (P_{Chl}) was measured to estimate Pmic. In a long-term improved pasture experiment, P_{Chl} was higher in grass-legume (GL) than grass-only pasture (GO). Although the P balance was slightly higher in GO than in GL, available P contents followed the same trend as P_{Chl} suggesting that the presence of legumes enhances the maintenance of P fertility. In a rice-pasture system, P_{Chl} was higher than under rice monocrop indicating an effect of the cropping system on PChl that goes beyond P inputs, and includes factors such as soil cultivation, herbicide application and organic matter input. Pmic may not be seen as a factor competing for plant available P in these strongly P-sorbing soils, but as a rapidly cycling pool that protects P from sorption. The results suggest that P_{mic} is an important indicator of P fertility on low P acid soils.

KEYWORDS

Oxisol, improved pastures, rice pastures, microbial P, soil P fertility, low P acid soils

INTRODUCTION

Phosphorus (P) deficiency is probably the most important constraint to agricultural production on tropical savanna soils, which are predominantly high P-sorbing Oxisols. The productivity and sustainability of agricultural production systems based on these soils depends on the introduction of improved adapted crops and forages and the efficient use and recycling of strategic P inputs. The objective of this study was to investigate the effect of P inputs and various agropastoral systems including improved tropical grasses, legumes and rice, on microbially bound P (P_{mic}). The relation of this pool to available inorganic P is analyzed to understand if it acts as an additional sink for P added by fertilizers, or if it may be considered as a rapidly cycling pool that protects P from strong sorption by iron and aluminum oxides and that helps to sustain soil P fertility.

MATERIALS AND METHODS

Soil samples were taken from the top soil (0-10 cm) of two long-term field experiments located on Oxisols (tropeptic haplustox isohyperthermic) in the Eastern Plains of Colombia. Both soils have medium to high P sorption capacity. Clay, silt and sand contents of the 0-10 cm layer were 39, 42 and 19% respectively at Carimagua and approximately 40%, 30% and 30% at the Matazul site. Soil pH ranged from 4.7 to 4.9 over all treatments at both sites, with 95% aluminum saturation in native savanna soils.

At the Carimagua site (Lascano and Estrada, 1989), a 15-year-old improved grass only (*Brachiaria decumbens*, cv. Basilisk) (GO) and grass-legume (*B. decumbens* + *Pueraria phaseoloides*, Kudzu) (GL) pasture and a native savanna control (SA) were sampled. At the Matazul site, native savanna was broken in 1989, and two experiments were laid out next to each other, the first involving a rice-pasture rotation, and the other continuos rice. The rice-pasture rotation included the following treatments (Gijsman *et al*., submitted):

- R-GO: Rice in 1989: grass-only (*Brachiaria dictyoneura* cv. Llanero) pasture 1989-1993.
- R-GL: Rice in 1989; grass-legume mixture *Brachiaria dictyoneura* cv. Llanero and *Centrosema acutifolium* cv. Vichada 1989-1993.
- R-GO-R: as R-GO, but resown to rice in May 1993.
- R-GL-R: as R-GL, but resown to rice in May 1993.
- CR: Continuous rice cropping since 1989.
- SAV: Neighbouring native savanna, which had been under traditional extensive management; control.

At Matazul, soil sampling was done in October 1993, less than one week after the rice harvest. At Carimagua, samples were taken at three dates (Table 2). Soil P status was characterized using anion exchange resin (Tiessen and Moir, 1993), Bray II (0.1 M HCl, 0.03 M NH4F) extraction and a total soil P determination after perchloric acid digestion. Chloroform released P (P_{Chl}) was measured to estimate microbially bound P (Morel *et al*., 1997; Oberson *et al*., 1997).

RESULTS AND DISCUSSION

The P balance for all cropping systems was positive relative to the unfertilized savanna (Table 1). The P inputs are the management response to the low available and total P of these highly weathered soils (Table 2). P export data for the improved pastures at Carimagua, for example, show that modest P fertilizer inputs, together with improved forage germplasm, has led to highly increased meat production when compared to native savanna.

Despite the medium to strong sorption capacity, fertilization and positive total P balances resulted in increased available inorganic P (Pi) contents extracted by resins and Bray II (Table 2). At the 15 year old Carimagua site, though, the positive P balance of the improved pastures was accompanied by lower resin- and Bray-P_i contents than in the rice-pastures at Matazul with similarly improved total P balances (R-GO-R and R-GL-R, Table 2). This may be due to the regular fertilizer application since 1978 at Carimagua, whereas fertilization started only in 1989 at Matazul. A greater part of fertilizer P has moved into less available pools over the years at Carimagua.

P_{Chl} increased both under improved pastures and rice-pastures (Table 2). At Carimagua, the increase was greater for GL than for GO although fertilizer P inputs were nearly identical (Table 1). This indicates that the legume increased P_{mic}. This effect was not seen in the younger rice-pasture experiment at Matazul. Besides the short experimental duration, soil cultivation before rice might suppress the legume effect.

Differences among improved pastures at Carimagua disappeared if sampling was done during the dry season when PChl decreased in all treatments (Table 2). As sampling at Matazul was done under diminishing rainfall late in the rainy season, decrease and leveling of P_{Chl} among treatments may already have started.

At Matazul, the cropping system effect on P_{Chl} went beyond P inputs.

P_{Chl} first increased with increasing available P contents and P balances, but remained level in rice-pastures that were resown to rice in 1993, and it decreased under continuos rice despite its highest available P contents and the most positive P balance (Table 1, 2). Rice is associated with more intensive soil cultivation and modified quantities and timing of plant residue inputs (Gijsman *et al*., submitted). In addition, herbicide application in continuous rice plots in 1993 might have decreased microbial populations and P_{Chl}.

In the improved pastures at Carimagua, an overall improved soil fertility was also indicated by other biological and chemical soil parameters and by improved productivity (Decaens *et al*., 1994, Rao *et al*., 1994) which was more pronounced for GL than for GO. At Matazul, microbial activity was increased under rice-pastures, but not under rice monocrop (Gijsman *et al*., submitted). Decreasing yields were observed in the rice-monocropping system (Sanz *et al*., 1994) especially because of weed problems.

The results of this study suggest that, in these soils, P_{Chl} can serve as an indicator of soil P fertility, and possibly the long-term resilience of P cycling on low-P acid soils.

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Table 1
Estimated P budget over 15 and 4 years for, respectively, the field experiments at Carimagua and Matazul: P input by fertilizers, P export by beef and/or rice, and calculated P balance.

Site /Treatment	Input	Export†	Balance
	kg P ha^{-1}		
Carimagua (1978-93)			
GO	103	24	+79
GL	106	36	+70
SA	-	2.1	-2.1
Matazul(1989-93)			
R-GO	50	14	36
R-GL	50	15	35
R-GO-R	100	18	82
R-GL-R	100	20	80
CR	215	31	184
SAV	-	0.7	-0.7

† Calculated from animal live-weight gains and rice harvests, assuming average P concentrations of 8.0 g kg-1 in the animals (ARC, 1980) and 2.4 g kg-1 in the paddy rice.

Table 2
P status in the 0-10 cm soil layer under native savanna, improved pastures, rice-pastures and rice monocrop.

Site / Treatment	Resin-P_i	Bray II - P	Total P	P_{Chl} Date 1	P_{Chl} Date 2	P_{Chl} Date 3
	mg P kg-1					
Carimagua†						
SA	3.5 (0.6)	1.3 (0.4)	185 (9)	5.2 (0.8)	3.0 (0.5)	4.4 (0.7)
GO	4.0 (0.4)	1.4 (0.5)	207 (15)	5.9 (1.0)	4.5 (1.3)	5.5 (1.2)
GL	5.2 (1.1)	2.2 (0.7)	245 (25)	7.3 (2.2)	4.5 (1.7)	7.5 (1.0)
Matazul‡						
SAV	2.1 (0.4)	5.7 (1.1)	177 (13)	3.9 (1.4)	-	-
R-GL	3.0 (0.9)	7.8 (1.6)	209 (13)	5.2 (0.4)	-	-
R-GO	3.1 (0.3)	6.4 (0.7)	221 (29)	4.6 (0.7)	-	-
R-GL-R	8.3 (0.7)	21.2 (5.6)	250 (14)	5.2 (0.7)	-	-
R-GO-R	9.4 (3.7)	23.5 (8.8)	255 (23)	5.4 (0.7)	-	-
CR	11.0 (1.5)	32.2 (3.9)	307 (35)	3.9 (0.8)	-	-

† Soil samples taken towards the end of the rainy season (September 1993), with exception of P_{Chl} sampling date 2 (dry season, January 1994)) and date 3 (Beginning of the next rainy season, April 1994). Means and standard deviations (in brackets) of 8 samples taken per treatment.

‡ Soil samples taken at the beginning of the dry season, October 20, 1993. Means and standard deviations (in brackets) of 3 (Resin-Pi) or 6 samples (other variables) analyzed per treatment.