Tropentag 2007
University of Kassel-Witzenhausen and
University of Göttingen, October 9-11, 2007
Conference on International Agricultural Research for Development

Changes in Inorganic and Microbial Biomass P Fractions over Time Following Goat Manure and Inorganic Phosphate Addition to a Moderately High P Fixing Soil

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INTRODUCTION

Soil phosphorus (P) is the least mobile and least available of the major plant nutrients. Its low availability has been described as `the bottle-neck of world hunger' (Rorty, 1946) and is a major constraint to agricultural production in most South African soils (Henry and Smith, 2006). Phosphorus deficiency in most tropical soils is mainly caused by strong sorption of P by aluminum (Al) and iron (Fe) oxides and hydroxides and other amorphous materials. This necessitates large applications of fertilizer P to overcome P fixation and to achieve high crop yields. This is unaffordable by resource poor smallholder farmers. It is therefore important to investigate affordable P management systems that optimize the integrated use of all P sources (e.g. fertilizers, organic manures, and waste materials) for the maintenance of soil fertility and crop productivity. Incorporation of P into the soil microbial biomass represents a significant pool of potentially available plant nutrients. This pool is said to play a key role in P dynamics in soils by immobilizing inorganic P, which may then be released slowly and taken up by the crop more efficiently during microbial biomass turnover (Brookes, et al. 1984). Our objective was therefore to evaluate the effects of combined additions of goat manure (readily available on most smallholder farms) and inorganic P on the size and distribution of biomass P and inorganic P pools (resin P, $NaHCO_3$-P_i and NaOH-P_i) in a moderately high P fixing soil from the Transkei region of South Africa.

MATERIALS AND METHODS

Two hundred and fifty grams of air-dry soil (< 2 mm) were weighed into plastic containers and treated with 0, 45, 90, 135 and 180 mg P kg^{-1} as triple supper phosphate (sieved < 1 mm) with or without goat manure (equivalent to 20 t ha^{-1} on a dry weight basis). The amended soils were then mixed thoroughly and moistened to 80% field capacity. Two small holes were made in each container lid to permit aerobic conditions during incubation. Sufficient replicates were prepared for each treatment to allow sampling at 7, 14, 28, 56, and 84 days, with three replicates at each sampling time. The samples were replicated three times and incubated in the dark at 25 ± 1 ^{o}C. The moisture level of the samples was monitored and adjusted weekly. At each sampling, resin P, biomass P and inorganic P fractions ($NaHCO_3$-P_i, and NaOH-P_i) were determined.

The resin strip method of Kouno et al. (1995) was used. Three sets of moist soil (2 g oven-dry basis) were prepared. The first set was treated with 1 ml of alcohol free $CHCl_3$ and fumigated for 24 hours at room temperature. Two anion and two cation exchange resin strips (10 mm x 60 mm) and distilled water (20 ml) were then added and shaken for 16 hours at room temperature at 175 oscillations per minute. The second set of soils received distilled water, 2 strips of anion and cation exchange and was then shaken, as described above. The third set was spiked with P equivalent to 50 ug P g^{-1} soil as KH_2PO_4 (20 ml) followed by P extraction with resin strips as described above. After shaking, the resin strips were removed from the soil extracts with tweezers and thoroughly rinsed with distilled water. The P adsorbed by the resins strips was recovered in 20 ml of 0.5 M HCl after shaking for 30 minutes. The inorganic P in the eluents was then determined (Murphy and Riley, 1962). The analyses were done in triplicate.

The soil suspensions remaining after the resin strips were removed from the $CHCl_3$ treated sets were centrifuged at 10,000 rev min^{-1} for 10 minutes and the supernatants discarded. Then, 30 ml of 0.5 M $NaHCO_3$ (pH 8.5) was added to the residue and shaken for 16 hours at 175 oscillations per minute. The suspensions were then centrifuged at 10,000 revolutions min^{-1} for 10 minutes and the solutions decanted into plastic containers. To the remaining soil residue of each sample, 30 ml of 0.1 M NaOH was added and shaken for 16 hours, centrifuged at 10,000 rev min^{-1} for 10 minutes and the solution decanted into plastic bottles. The P in the supernatant was then determined by the molybdate-ascorbic acid method (Murphy and Riley, 1962). Biomass P (B*p*) was calculated as described by Brookes et al. (1982). Statistical analysis was done using GenStat statistical software (GenStat Release 4.24DE, 2005)

RESULTS AND DISCUSSION

The results presented here are confined to samples taken on day 28 when major changes in P fractions were observed. The P recovered in the different fractions was strongly dependent on the amount of added P suggesting that an external source of inorganic P was necessary to increase their pool sizes. The proportions of the three inorganic P fractions extracted were in the order NaOH–P_i>Resin-P>$NaHCO_3$ –P_i (Table 1).

Table 1 The effects of inorganic P and goat manure (GM) addition on the distribution of P fractions after 28 days of incubation

Added P (mg P kg^{-1})	Total P^{ϕ} (mg P kg^{-1}) (T)	P fractions (mg P kg^{-1})				% Biomass P of total P b/T *100%
		Resin P (a)	Biomass P (b)	$NaHCO_3$ -P_i (c)	NaOH-P_i (d)	
Without goat manure						
0	420	17.2 j	16.8 b	11.8 g	144.3 f	4.0 d
45	465	39.6 h	30.7 b	17.9 f	164.3 e	6.6 cd
90	510	59.2 f	45.9 b	24.9 d	193.5 d	9.0 cd
135	555	93.63 d	49.6 b	34.3 b	227.9 b	8.9 cd
180	600	118.2 b	43.9 b	41.7 a	250.6 a	7.3 cd
With 20 ha^{-1} goat manure						
0	434	27.5 i	32.6 b	13.9 g	107.5 g	7.5 cd
45	479	54.6 g	50.2 b	21.1 e	149.5 f	10.5 bc
90	524	73.5 e	87.7 a	28.3 c	171.0 e	16.7 ab
135	569	103.9 c	97.7 a	35.6 b	196.0 d	17.2 a
180	614	122.7 a	96.9 a	41.4 a	213.2 c	15.8ab
$LSD_{(0.05)}$	-	4.0	34.5	3.1	13.3	6.7
Cv (%)	-	3.3	36.7	6.7	4.3	8.5
s.e.d	-	1.8	16.5	1.5	6.4	3.2

Means followed by the same letters within columns are not statistically different (p = 0.05) $^{\phi}$ Soil total P + added goat manure and inorganic P (mg kg^{-1}), s.e.d = standard error of difference of treatment means

Soil NaOH-P_i was the largest extractable P_i fraction and thus was the major sink for the applied P. According to Hedley et al. (1982) this fraction is less plant-available and usually associated with humic compounds and amorphous and some crystalline soil Al and Fe oxides. The NaOH-P_i fraction was relatively smaller in soils where added P was applied with goat manure than when added P was applied alone indicating that the presence of goat manure helped to minimize the fixation of added P in the soil. This confirms other results (e.g. Iyamuremye et al., 1996) showing that addition of organic materials to soil decreases P fixation. Inorganic P addition increased biomass P which was further enhanced by manure addition (Table 1). Kouno et al. (2002) attributed such increases in biomass P to uptake of inorganic P from added fertilizer P into microbial biomass and conversion into other forms of P such as polyphosphates and metaphosphates that serve as cellular storage products. The increase in biomass P in the presence of goat manure apparently occurred at the expense of the NaOH-Pi fraction, showing the

protective effect of biomass P on added P. More recently, Ayaga et al. (2006) reported similar results following manure application to soil in field experiments in Kenya. They postulated that addition of manure stimulates the synthesis of soil microbial biomass resulting in increased demand for P, which becomes immobilized in labile forms in the cells of the living soil micro-organisms and associated pool of microbial metabolites. This implies that application of goat manure together with small inputs of P fertilizers could be a cost effective way of increasing P fertilizer use efficiency on smallholder farms in South Africa, where goat manure and other animal manures are available.

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Acknowledgement

We acknowledge with gratitude the financial support from Nation Research Foundation and the University of Fort Hare for providing laboratory facilities. We also acknowledge with gratitude, The Director, Kenya Agricultural Research Institute for granting study leave to the first author.