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Improving rock phosphate availability through feeding, mixing and processing with composting manure

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Abstract

The objective of this study was to improve the availability of phosphorus (P) from rock phosphate (RP) through feeding, mixing and composting manure. The experiment was conducted as a 3×2 split-plot design. Manure was collected from 12 Boran steers (200 ± 4.5 kg live weight) fed a basal diet of Napier grass (*Pennisetum purpureum*) at 2.5% body weight on a dry matter (DM) basis. The main plot treatments were (i) manure from steers supplemented with 113 g Busumbu rock phosphate (BRP) per day (FBRP), (ii) manure from steers not supplemented with BRP, feces mixed with 113 g BRP per day (MBRP) and (iii) manure from steers not supplemented with BRP and feces not mixed with BRP (CONT). The sub-plots comprised composting the manure either (i) mixed with 440 g of wheat (*Triticum aestivum* L.) straw per kg fresh feces (WS) or (ii) without straw (WOS). The manure was composted in 200 L plastic bins for 90 days. After 90 days, P availability was evaluated (i) by aerobic laboratory incubation at 25 °C for 1, 2, 4, 8, 12, and 16 weeks and (ii) by greenhouse agronomic evaluation study using maize (*Zea Mays* L.) as the test crop in either a humic Nitosol or an Andosol. In the laboratory incubation study, resin P was higher ($p < 0.05$) for the WS compost than for the WOS compost; values were higher ($p < 0.05$) for the Andosol than for Nitosol and followed the order of FBRP–WS, Andosol > FBRP–WS, Nitosol > MBRP–WS, Andosol > MBRP–WS, Nitosol > FBRP–WOS, Andosol > FBRP–WOS, Nitosol. In the greenhouse evaluation, maize crops in the WS compost had higher ($p < 0.05$) biomass yield than the reference fertilizer, triple super phosphate, (173% versus 196%; Andosol and Nitosol, respectively). The biomass yield and P uptake relative agronomic effectiveness (RAE) for WS compost was also higher ($p < 0.05$) than that of WOS compost (184 versus 3 ± 0.8 and 242 versus 162 ± 0.2, WS and WOS, biomass yield and P uptake, respectively). Nitosol biomass yield and P uptake RAE were also higher ($p < 0.05$) than for the Andosol (99 versus 88 ± 0.8 and 332 versus 72 ± 0.2, Nitosol and Andosol, biomass yield and P uptake, respectively). The results show that P-enriched composting in the presence of wheat straw significantly increased P availability and increased plant growth. However, in terms of plant growth, there was no additional benefit of first feeding the RP to steers before composting the manure because most of the RP fed seem to have been utilized by the animal.

Keywords: Composting; Maize; Phosphorus availability; Rock phosphate

1. Introduction

In sub-Saharan Africa, soil nutrient depletion is a major biophysical factor contributing to decrease or stagnated agricultural productivity (Sanchez et al., 1997). Most soils are characterized by deficient levels of plant-available phosphorus (P) (Buresh et al., 1997). This deficiency has

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been attributed to the inherently low level of P in the parent materials, the high P fixation by aluminium and ferrous oxides (Buresh et al., 1997) and to the intensive cropping practiced with low nutrient input (Shepherd et al., 1996). It follows, therefore, that numerous field experiments have shown crop responses to small and/or moderate application of soluble P fertilizers (Hammond et al., 1986; Tekalign and Haque, 1987; Okalebo et al., 1992). However, many smallholder farmers lack the financial resources necessary to purchase sufficient fertilizers to either correct the inherent low levels of P in the soil or replace the P exported with harvested products (World Bank, 1994; Sanchez et al., 1997).

The high cost of importing soluble P fertilizers is, therefore, forcing many developing countries to turn increasingly to using local rock phosphate (RP) resources to improve agricultural production (Van Kauwenbergh, 1991; Buresh et al., 1997; Van Straaten, 2002). In east Africa, for example, one such deposit, which is easily accessible and has abundant reserves, is the Busumbu deposit at Busumbu Hill in Uganda which has been estimated to contain 5–8.5 million tonnes of RP of between 3.5% and 15.3% P (Van Kauwenbergh, 1991; Katto, 1995; Van Straaten, 2002). However, Busumbu rock phosphate (BRP), like most phosphate deposits of igneous origin, has low reactivity and might not be suitable for direct application (Van Straaten, 2002).

Several alternative approaches have been used or proposed to increase P availability in RP including: (1) incorporation of additives into RP, (2) partial acidulation of RP, (3) compaction of RP with water-soluble P fertilizers, and (4) microbial methods (Van Straaten, 2002). Composting manure and/or biological waste with RP has been shown to enhance the dissolution of the RP (Mishra and Bangar, 1986; Singh and Amberger, 1991) and is practiced widely as a low-input technology to improve the fertilizer value of manure (Mahimairaja et al., 1995). However, although research has focused on the quality of compost organic matter (Adani et al., 1997; Liang et al., 1996; Requena et al., 1997) and on the forms and availability of compost nitrogen (N) (Kuo, 1995; Sanchez et al., 1997), little has been done to unravel the forms and availability of P. The hypothesis for the present study, therefore, was that composting would enhance the dissolution of the RP and that the effectiveness of RP for plant P uptake and growth would be enhanced the most by first feeding the RP to cattle and then composting the manure from the animals. The objective of this study was to improve the availability of P from RP through feeding, mixing and composting manure.

2. Methods

2.1. Site and soils

This work was conducted at Kenya Agricultural Research Institute Muguga, Kenya. The station is located 27 km west of Nairobi at a latitude 1°13' 53.0'' South, longitude 36° 38'' 1.1' East and an altitude of 2000 m above sea level. The soils used in the incubation and greenhouse study were collected from a humic Nitosol and an Andosol (FAO classification) site with no prior history of fertilizer use. A single composite soil sample was collected from each location at a depth of 0–20, air-dried and ground to pass through a 2 mm sieve, while another portion was ground to pass an 100 mesh (150 μm) sieve. The pH of the soil was measured in deionized water (1:2.5 soil: solution ratio) and particle size distribution determined using the pipette method after pre-treatment to remove soluble salts, organic matter and carbonates (Gee and Bauder, 1986). Organic carbon contents were determined using the dichromate oxidation method of Walkley and Black (Nelson and Sommers, 1982), exchangeable bases using excess 1 M NH_4OAc and micronutrients Zn, Cu, Mn and Fe as described by Anderson and Ingram (1996). Maximal soil P sorption was obtained in duplicate by equilibrating 3 g of the soil with 30 mL of 0.01 M $CaCl_2$ in 50 mL plastic centrifuge tubes as described by Anderson and Ingram (1996). Various amounts of P (0–20 mg L^{-1}) were added as KH_2PO_4 and the samples equilibrated for 6 d. A few drops of toluene were added to the mixture to suppress microbiological activity and the samples were shaken on a reciprocal shaker at a speed of 100 cycles per min. At the end of the equilibration period, the aqueous solution was separated by a combination of centrifugation (4800*g* for 10 min) and filtration (Whatman No. 40). The concentration of P in solution was then determined by the molybdate-ascorbic acid method (Murphy and Riley, 1962). The amount of P sorbed was calculated as the difference between the amount of P added and that remaining in solution (Fox and Kamprath, 1970). Selected properties of the soils are presented in Table 1.

2.2. Treatments and experimental design

The experiment was conducted as a 3 × 2 split-plot design. Composting manure was collected from 12 Boran steers (200 ± 4.5 kg live weight) fed a basal diet of Napier grass (*Pennisetum purpureum*) at 2.5% body weight on a dry matter (DM) basis. The main plot treatments were (i) manure from steers supplemented with 113 g Busumbu rock phosphate (BRP) per day (15 g P per day is the P requirement for maintenance for a 200 kg steer; National Research Council, 2001) (FBRP), (ii) manure from steers not supplemented with BRP, feces mixed with 113 g BRP per day (MBRP) and (iii) manure from steers not supplemented with BRP and feces not mixed with BRP (CONT). The sub-plot comprised of composting the manure (i) either mixed with 440 g of wheat (*Triticum aestivum* L.) straw per kg fresh feces (WS) or (ii) without straw (WOS) to give six treatments i.e., FBRP–WS, FBRP–WOS, MBRP–WS, MBRP–WOS, CONT–WS and CONT–WOS. The BRP contained 1.84%Si; 0.57%Al; 7.2%Fe; 0.1%Mg; 33.7%Ca; 0.02%Na; 0.02%K; 0.08%Ti; 0.34%Mn and 14.2%P (X-ray diffraction analysis, Geosci-