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Phosphorus availability to maize as influenced by organic manures and fertilizer P associated phosphatase activity in soils

Shipra Garg *, G.S. Bahl

Department of Soils, Punjab Agricultural University, Ludhiana, India

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Abstract

Laboratory incubation and green house studies were conducted to compare the P availability of organic manures and P uptake from organic manures by maize. Various organic manures viz. Poultry manure (PM), Farmyard manure (FYM), Green manure (GM) and Crop residue (CR) and graded levels of fertilizer P were applied in Samana sandy loam and Ladhowal silt loam soils and incubated for 7, 15, 30, 60 and 90 days. Samples were analyzed for P availability, P uptake and alkaline phosphatase activity. The overall, phosphatase activity, Paranitrophenyl phosphate (PNP h^{-1} g^{-1}), in the Ladhowal silt loam soil was higher than in the Samana sandy loam soil. As the level of inorganic P increased, the release of PNP h^{-1} g^{-1} soil also increased. Among different organic manures, PM registered the highest enzyme activity followed by FYM, GM and CR. Compared to 7 days incubation a slightly higher increase in PNP was noticed in samples from 90 days incubation in both soils. The differential phosphatase activity in the organic manures was further reflected in dynamic P availability. The highest amount of Olsen extractable P was in PM-treated soil followed by FYM, GM and field pea crop residue. Organic manure addition along with inorganic P, irrespective of the source, increased the Olsen extractable P throughout the incubation period. Total P uptake by maize increased with the increasing level of inorganic P in both soils. The highest uptake was obtained in PM-treated soil and lowest in the CR-amended soil. We conclude that PM more readily supplies P to plants than other organic manure sources.

Keywords: Organic manures; P availability; Alkaline phosphatase activity

1. Introduction

Phosphorus is an essential nutrient element required for plant growth and development. However, due to the highly reactive nature of phosphate anions, these may be immobilized through sorption and/or precipitation with cations such as Ca^{2+}, Mg^{2+}, Fe^{2+} and Al^{3+}. As a result of this immobilization, P concentration in soil solution seldom exceeds 0.1 ppm. This calls for increasing the use efficiency of phosphatic fertilizers through various means. Combined use of chemical fertilizers with organic manures or crop residue in an appropriate ratio can result in increased nutrient availability and crop yields (Kumar et al., 1999). Phosphatases play an important role in nutrient P availability of organic manures/crop residue. The general name "phosphatases" describes a broad group of enzymes that catalyze the hydrolysis of both esters and anhydrides of phosphoric acid (Schmidt and Laskowski, 1961). The phosphatase activity in soils has been studied earlier by many workers, but most of these studies have been confined to the activity of acid phosphatase, predominant in low pH soils. These enzymes can contribute to P nutrition, provided the organic substrate is present. Phosphatase activity is expected to be enhanced by the application of various organic manures, which manifests in enhanced P availability in soil. Use of FYM (El-Baruni and Olsen, 1979), green manure (Bahl and Singh, 1993) and poultry manure (Toor and Bahl, 1997) have been reported to enhance P

* Corresponding author.

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availability in soils. The comparative efficiency of different organic manures in enhancing the P availability in relation to alkaline phosphatase activity under alkaline soil conditions has not been well documented. Organic manures/crop residue additions also result in direct addition of P as well as acceleration of native P solubilization by release of weak organic acids. Native P and addition of fertilizer P is also reported to affect the activity of phosphatase (Kiss et al., 1974). Thus phosphatase activity and soil P availability appear to complement each other. This study was conducted to evaluate the activity of alkaline phosphatase as affected by the combined and separate application of various organic manures and graded fertilizer P levels in relation to P availability in soil. The results of laboratory study were verified by growing a maize crop with the same set of organic manure and P treatments.

2. Methods

Surface (0–25 cm) samples of two soils, one calcareous and another non-calcareous, collected from Punjab Agricultural University Farm, Ladhowal and Ludhiana, respectively, were ground to pass through a 0.2 mm sieve for the laboratory incubation experiment. The important physical and chemical characteristics of the soil are given in Table 1. The organic manures viz. PM, FYM, GM and CR were analysed for total carbon, nitrogen and phosphorus Wakley and Black (1934), Dalal et al. (1984) and Chapman and Pratt (1961) are in Table 2a and b. These were also analyzed for hemicellulose, cellulose, lignin and ash content by using Goering and Vansoest (1970) methods (Table 2c).

These organic manures were added at 1785.7 $\mu g\ g^{-1}$ (4 $Mg\ ha^{-1}$) to a two-kg sample of each soil on uniform dry weight basis. PM (deep litter system) and FYM were obtained from Punjab Agricultural University, Ludhiana – poultry and dairy farm, respectively. Cowpea (*Vigna unguiculata*) and field pea (*Pisum sativum*) was raised in the field for subsequent use as green manure (60 days old) and crop residue at maturity, respectively. Each set of four samples containing organic manures were further divided into four parts and to each part, fertilizer P was applied at 0, 6, 9 and 12 $\mu g\ g^{-1}$ through monocalcium phosphate solution. Another set was maintained with addition of only fertilizer P solution at the above-mentioned rates (without any organic manure i.e. control). Five such sets were prepared and one set was removed at 7, 15, 30, 60 and 90 days. Two drops of toluene were added to each container to prevent the fungal growth. The treated soils were incubated at 32 ± 2 °C. Moisture was maintained at 50% of field capacity by daily weighing the containers and making up the loss of water while stirring the soil. Alkaline phosphatase activity (PNP, $\mu g\ h^{-1}\ g^{-1}$ soil) was estimated in soils incubated for 7 and 90 days by the method of Eivazi and Tabatabai (1977). Olsen extractable (Olsen et al., 1954) P was estimated in the soil samples from all incubation periods.

The pot experiment was conducted using the same soils. Four kilogram of each soil was packed in pots after treating them with same levels of fertilizer P and organic manures as in the laboratory incubation study, besides an absolute control. The treatments were replicated three times. A basal dose of N, K and Zn at 56, 11.2 and 2.5 $\mu g\ g^{-1}$ was added through urea, muriate of potash and zinc sulphate, respectively. Because organic manures also contained major nutrients such as N, K and S, the pots not receiving organic manure were supplemented with equivalent amount of these nutrients from inorganic source. Six maize seeds (Cv. Paras) were planted in each pot, which were later thinned to three per pot. Irrigation to pots was applied when upper 1 cm soil layer dried up. The crop was harvested after 60 days growth and plant samples were analysed for total P by Vanadomolybdic yellow colour method (Jackson, 1967).

2.1. Statistical analysis

The data from both laboratory and pot culture experiments were statistically analyzed by factorial completely randomized design. Correlations among various parameters studied in laboratory were worked out and significance of different treatments was tested using methods of variance as described by Snedercor (1961).

Table 1
Analysis of two soils used in the organic manure incubation experiment

Soil properties	Samana sandy loam	Ladhowal silt loam
Taxonomic classification	Typic Ustochrepts	Typic Ustifluvents
pH (1:2)	7.5	7.9
Organic carbon ($g\ kg^{-1}$)	2.6	4.0
Clay (%)	11.4	16.6
Silt (%)	14.5	65.0
Sand (%)	73.6	18.5
$CaCO_3$ (%)	Absent	1.40
Available P ($kg\ ha^{-1}$)	11.5	16.3

Table 2
Composition of organic manures used in the incubation experiment

Nutrient	Poultry manure	Farmyard manure	Green manure	Crop residue
(A) Nutrient content of organic manure (%)				
C	0.59	0.33	0.09	0.14
N	1.87	1.23	0.71	0.36
P	1.27	0.80	0.27	0.15
(B) Nutrient ratios				
C: N	32:1	27:1	13:1	40:1
C: P	46:1	25:1	33:1	93:1
(C) Biochemical constituents (% of dry matter)				
Hemicellulose	25.0	18.0	27.6	25.0
Cellulose	63.0	38.0	43.5	43.0
Lignin	5.0	17.8	19.0	28.0
Ash	7.0	12.3	1.5	3.0