PHOSPHORUS RETENTION IN AN ALFISOL AMENDED WITH LIME AND GYPSUM

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We investigated P retention by an Alfisol treated with lime and gypsum. For this purpose a surface sample of Pindorian series (Udic Haplustalf) receiving either lime or gypsum @ 200 g kg⁻¹ soil was incubated under lab condition after adding P @ nil and 100 mg P kg⁻¹. Soil treatment with lime and gypsum significantly (p < 0.001) decreased water-soluble and NaHCO₃ extractable (Olsen) P in descending order at different rates of P application. On an average, reduction in NaHCO₃ extractable P by lime addition was 36 % (range 30 to 37 %) which was 52 % (range 48 to 53 %) by gypsum addition. Relationship between water-soluble and soil retained (sorbed) P was best described by the Freundlich equation. Two P sorption equations at low (5 to 25 mg P kg⁻¹ soil) and high (50 to 300 mg P kg⁻¹ soil) rates of P application were observed for lime-amended soil. An augmented tendency of P retention by solid phase was revealed by higher intercept and slope values calculated for Freundlich equation in lime and gypsum amended soils. Further studies on P release pattern are suggested in lime and gypsum amended soils, which would be important for plant nutrition.

Key words: P application- calcareous soils- P nutrition- Olsen P

INTRODUCTION

Application of phosphatic fertilizer is a common practice for realizing economic crop yields under arid and semi-arid environments. These soils, generally developed under hot and dry climate, are characterized by excessive accumulation of lime (calcium carbonate) and gypsum (calcium sulfate) in their profile (Eswaran and Zi-Tong, 1991). Occurring as concretions and/or as powder and or in both forms, throughout the soil profile or by concentrating in certain zones lime results in calcic and petro-calcic horizons and gypsum yields gypsic or petro-gypsic horizons (Buol, et al., 1997). Also bulk quantities of lime are added to control soil acidity and gypsum is applied to combat soil sodicity. Reactions of applied P with lime (calcium carbonate) and its availability in calcareous soils has been the subject of several publications (Freeman and Rowell, 1981; White, 1981; Kissel et al., 1985; Rahmatullah and Torrent, 2000 and Curtin and Syers, 2001). Reduced bioavailability of P in calcareous soils has been reported (Aff et al., 1993 and Wang and Tzou, 1995) due to their strong soil pH buffer system controlled, mainly by free lime (Brukert and Rouiller, 1982 and Kissel et al., 1985). However, effect of gypsum on P availability to plants has rarely been reported (Shainberg et al., 1989 and Bastin et al., 1999). Tunesi et al. (1999) have preluded the predominant role of Ca ion in P immobilization under calcareous soil conditions. Both lime (CaCO₃) and gypsum (CaSO₄·2H₂O) are common Ca containing minerals under arid soil environment with different counter balancing anion indicating their different soil chemistry. Their comparative effect on P availability in soils has rarely been reported (Khasawneh, et al., 1980). The present study was, therefore, conducted to elucidate the role of lime and gypsum on NaHCO₃ extractable (Olsen) P and distribution of applied P between solid and solution phases of soil.

MATERIALS AND METHODS

Soil Amendment with lime and gypsum

Representative bulk surface (0-15 cm) soil sample for Pindorian series (coarse-loamy, mixed, hyperthermic Udic Haplustalf) collected from the bench mark site (Ahmad et al., 1985) was air dried and ground to pass through 2 mm sieve. The proportion of different size particles analyzed in the prepared soil sample by hydrometer (Gee and Bauder, 1986) was sand 592 g kg⁻¹, silt 297 g kg⁻¹and clay 111 g kg⁻¹. Organic matter estimated by Walkly-Black method (Nelson and Sommers, 1996) in the soil was 1 g kg⁻¹ and CaCO₃ by acid dissolution method (Loeppert and Suarez, 1996) was 34 g kg⁻¹. Soil pH measured in 1: 1 soil water suspension by calomel-glass electrode assembly using a Beckman pH meter was 7.8.

The prepared soil was mixed thoroughly either with lime (CaCO₃) or gypsum (CaSO₄·2H₂O) at the rate of 200 g amendment kg⁻¹ soil. Such amended soil was moistened and mixed manually thrice for equilibration and air dried and ground to pass through a 2-mm sieve before further experimentation.
Incubation Study

A 200 g portion of each of the original prepared sample of Pindorian soil, lime-amended soil and gypsum-amended soil taken in plastic pots received P @ 0, 5, 10, 25, 50, 100, 150 and 300 mg P kg\(^{-1}\) soil in duplicate in solution form as KH\(_2\)PO\(_4\). Distilled deionized water was used to bring and maintain soil moisture content in pots at 60 percent of field capacity of the three soils. The pots were incubated at room temperature. After each of the three wetting and drying cycles, the soil in each pot was emptied, mixed thoroughly and repotted. Sodium bicarbonate extractable P (Kuo, 1996) was estimated after eight weeks of incubation period to calculate the recovery of P applied at different rates to the three soils as given below:

\[
\text{Recovery of applied P} = \left( \frac{P_f - P_c}{P_a} \right) \times 100
\]

Where \(P_f\) is NaHC\(_0\)\(_3\) extractable P in fertilized pot, \(P_c\) is NaHC\(_0\)\(_3\) extractable P in control pot and \(P_a\) is the rate of P application.

Water soluble (solution) P was estimated in clear supernatant by shaking soil in different pots at 1: 10 soil: water ratio for 18 hours. Sorbed P was calculated as the difference between applied and soluble P. Least square method of linear regression (Steel and Torrie, 1980) was used to fit the following logarithmic form of Freundlich isotherm to soluble and sorbed P (Evangelou, 1998).

\[
\log x /m = 1/n \log C + \log k
\]

RESULTS

Sodium bicarbonate extractable (Olsen) P

There was a significant (\(p < 0.001\)) main and interactive effect of gypsum and lime application on NaHC\(_0\)\(_3\) extractable P at different rates of P addition (Table 1). Both gypsum and lime application significantly (\(p < 0.001\)) reduced NaHC\(_0\)\(_3\) extractable P at different rates of P application. Lime amended soil tested minimum in NaHC\(_0\)\(_3\) extractable P. Sodium bicarbonate extraction recovered 8 to 21% of P, added at different rates to lime amended soil (Table 1). On an average, 17% of the added P was recovered by NaHC\(_0\)\(_3\) extraction in lime-amended soil. It was followed by NaHC\(_0\)\(_3\) extractable P in gypsum-amended soil in ascending order. Recovery of P by NaHC\(_0\)\(_3\) extraction in gypsum amended soil treated with different rates of P ranged from 26 to 40%. On an average, 28% of the added P was extractable by NaHC\(_0\)\(_3\) in gypsum-amended soil. Maximum proportion of P added at different rates was recovered by NaHC\(_0\)\(_3\) extraction of the original soil. Recovery of P applied at different rates by NaHC\(_0\)\(_3\) extraction of original soil ranged from 56 to 75% with an average recovery of 68% (Figure 1).

<table>
<thead>
<tr>
<th>Rate of P application (mg kg(^{-1}))</th>
<th>Amendment (@ 200 g kg(^{-1}) soil)</th>
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<tbody>
<tr>
<td>Control</td>
<td>Calcium carbonate</td>
</tr>
<tr>
<td>0</td>
<td>2.20</td>
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<tr>
<td>5</td>
<td>5.19</td>
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<td>10</td>
<td>7.78</td>
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<td>25</td>
<td>20.45</td>
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<td>50</td>
<td>36.95</td>
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<td>100</td>
<td>79.40</td>
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<td>150</td>
<td>115.40</td>
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<td>300</td>
<td>208.20</td>
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LSD\(_{0.01}\) for comparing P x soil amendment means is 1.97
Phosphorus retention in an alfisol amended with lime and gypsum

Fig. 1. Effect of lime and gypsum on P recovery as measured by NaHCO₃ extraction of soil.
Fig II. Phosphorus adsorption data plotted according to Freunlich equation
**Phosphorus sorption**

There was a significant ($p<0.001$) main and interactive effect of P and gypsum and lime application on water soluble P and P retained by the solid phase (Figure 2). Maximum proportion of 35 to 61 % of applied P was in water-soluble form in the original soil. Only 39 to 65 % of applied P at different rates was retained by soil solids. It was followed by gypsum-amended soil, which had 10 to 16 % of the applied P in water-soluble form. Only 84 to 90 % of the applied P was retained by soil solids in gypsum-amended soil. Minimum proportion of 0.03 to 0.50 % of P applied at different rates was in water soluble form in lime-amended soil. More than 99 % of the applied P was retained by solid phase in lime-amended soil. Relationship between soluble P and sorbed P in the original soil, lime amended soil and gypsum amended soil was described by Freundlich equation. In lime amended soil, two P retention mechanisms, one operative at low (5 to 25 mg P kg$^{-1}$ soil) and the other at high (50 to 300 mg P kg$^{-1}$ soil) P application rates were observed. This yielded two regression lines for P retention in lime-amended soil. This is in conformity with earlier workers (Freeman and Rowell, 1981 and Kissel et al., 1985) who have reported similar results about P retention in calcareous soils. However, different intercept and slope values were calculated for various soils.

**DISCUSSION**

Phosphorus fertilizers are used to correct commonly occurring P deficiency in plants grown on alkaline calcareous soils of arid and semi-arid environment (Malik et al., 1992). The added P is involved in several physical, chemical and biological reactions in the soil and its recovery is enormously low (Kissel et al., 1985). Rather major part of it is retained by the constituent minerals of soil solid phase (White, 1981), which are in equilibrium with soil solution phase bathing plant roots. Both lime and gypsum are important mineral phases of soil under hot and dry climatic regions of the world (Buol et al., 1997). Both, lime and gypsum, also significantly ($p < 0.001$) reduced extractability of added P by NaHCO$_3$ extraction, a common soil test procedure used to monitor P availability in calcareous soils (Kuo, 1996). Maximum P retained against NaHCO$_3$ extraction in lime-amended soil was followed by the gypsum-amended soil (Table 1). Recovery of applied P by NaHCO$_3$ extraction ranged from 8 to 24 % (mean 17 %) in lime amended soil, from 26 to 40 % (mean 33 %) in gypsum amended soil as compared to 56 to 77 % (mean 69 %) in the original un-amended soil. Similar trend was also evident in water soluble P, which estimated minimum in lime amended soil followed by the gypsum amended treated soil. Relationship between soluble and sorbed P was best described by the Freundlich isotherm. The two P sorption mechanisms operating at low (5 to 25 mg P kg$^{-1}$ soil) and high (50 to 300 mg P kg$^{-1}$ soil) application rates were evident in lime-amended soil, which was in conformity with earlier observation of other investigations (Freeman and Rowell, 1981 and Kissel et al., 1985). Higher values of intercept and slope calculated for Freundlich isotherm in the lime amended soil and gypsum amended soil also supported the augmented retention of added P by their solid phase.

**REFERENCES**


