

Phosphorus fixing capacity of the Oxic Rhodustalf—alfisol soil in the Chotanagpur plateau region of Eastern India

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ABSTRACT

The P-fixing capacity of a soil governs the P-nutrition of crop plants. P-nutrition of the crop plant is more a soil problem and a higher dose of phosphatic fertilizer is necessary for soils having high P-fixing capacity. The phenomenon of P-fixation and the great variation in the P-fixing capacity of different soils has thus important bearing on crop response to P-application. The eastern plateau region of India with acid lateritic soil is chronically deficient in available phosphorus resulting in very low productivity. An experiment was thus carried out to estimate the P-fixing capacity of soil collected from two depths, 0 - 20 cm and 20 - 50 cm, from the Agricultural experimental farm of Indian Statistical Institute, situated at Giridih, Jharkhand, in the eastern India. The soil was acidic in reaction (pH-5.4) with presence of Fe (1.60%) and Al (17.2%). The P-fixing capacity of the soil was estimated to be 59.60% and 64.94% for the surface and the subsurface soil respectively showing lower P-fixing capacity of the surface soil as compared to the subsurface soil which may be due to presence of more organic matter in the surface soil as organic molecules released on decomposition of organic matter complexes with Fe and Al in the soil thereby blocking the P-fixing sites in the soil.

Keywords: P-Fixing Capacity; P-Nutrition; P-Fixation

1. INTRODUCTION

Phosphorus (P) is an essential element for plant growth and productivity, and lack of available P in soils can se-

verely affect crop yields [1]. Plants extract P from the soil solution in the form of orthophosphate ion ($H_2PO_4^-$ or HPO_4^{2-}) and there is strong competition between plants and soil minerals for these forms of P, particularly in the highly weathered soils of the tropics, most of which contain large amounts of iron oxides, aluminum oxides, or amorphous alumino-silicate clays. These soil minerals “fix” P firmly through a process known as sorption, making the P virtually unavailable for plant uptake [2].

The P-fixing capacity of a soil is influenced by a number of factors, such as pH, $CaCO_3$, sesquioxides, moisture and clay contents [3]. When phosphatic fertilizers are added to a soil, a series of chemical reactions take place between the soil constituents and soluble phosphorus, rendering the added phosphorus relatively less available. The soil factors contributed to 80 to 83 per cent of the variations in the amounts of P fixed at various levels of added P and also of the maximum P fixation capacity [4]. Thus, it is now well understood that P-nutrition of the crop plants is more a soil problem and a higher dose of phosphatic fertilizers are thus necessary for soils having high P-fixing capacity. It has been reported that about 10% to 30% of added phosphorus, is utilized by the crop and the rest is accumulated in the soil in one form or another thereby enriching the reserve phosphorus pool of the soil. An increase in the Relative Agronomic Efficiency of less water-soluble P sources on high soil P adsorption capacity has also been reported [5]. Thus, the phenomenon of P-fixation and the great variation in P-fixing capacity of different soils has important bearing on crop response to phosphorus application.

The eastern plateau region of India is chronically low in productivity of food grains [6]. One of the reasons for this is attributed to very low phosphate availability of the soil (20 - 25 kg P_2O_5 /ha) due to its acidic reaction and presence of large amount of hydroxides of iron and alu-

minum [7].

With this background, an experiment was carried out in the laboratory of the Agricultural and Ecological Research Unit of Indian Statistical Institute at Kolkata, on soils collected from the Agricultural farm of Indian Statistical Institute situated at Giridih, Jharkhand in the Chotanagpur plateau region of eastern India.

2. MATERIALS AND METHODS

The composite soil samples were collected from Agricultural experimental farm of Indian Statistical Institute situated at Giridih, Jharkhand, from two depths, 0 - 20 cm and 20 - 50 cm. The soil samples were air dried, ground and passed through 2 mm sieve. The physico-chemical properties of the experimental soil are presented in **Tables 1(a)** and **(b)**.

Treatment Details :

Concentrations of P added as KH_2PO_4 ($\mu\text{g}/\text{cc}$)	Soil Taken (g)	Effective concentration on addition of 1 cc P solution in 2.5 g of soil ($\mu\text{g}/\text{g}$)	Soil sampling depth (cm)
0	2.5	0	0 - 20
50	2.5	20	20 - 50
100	2.5	40	
150	2.5	60	
200	2.5	80	
300	2.5	120	
400	2.5	160	
500	2.5	200	
600	2.5	240	
750	2.5	300	

3. METHODOLOGY

Two and a half gram (2.5 g) of air dried sieved soil was taken for each treatment, for two soil depths (0 - 20 cm and 20 - 50 cm depth), in 100 cc conical flask. One milliliter (1 ml) of different concentrations (0 $\mu\text{g}/\text{cc}$, 50 $\mu\text{g}/\text{cc}$, 100 $\mu\text{g}/\text{cc}$, 150 $\mu\text{g}/\text{cc}$, 200 $\mu\text{g}/\text{cc}$, 300 $\mu\text{g}/\text{cc}$, 400 $\mu\text{g}/\text{cc}$, 500 $\mu\text{g}/\text{cc}$, 600 $\mu\text{g}/\text{cc}$ and 750 $\mu\text{g}/\text{cc}$) of soluble phosphorus, in the form of potassium dihydrogen phosphate was carefully added to each flask as per treatment so as to wet the soil uniformly. The conical flasks were then plugged and incubated at room temperature (30°C) for 96 hours and available phosphate (P) was then estimated by Olsen's method [8]. The whole experiment was carried out in three sets and the mean data have been presented. According to Nad *et al.* (1975) the P-fixation capacity of soil was worked out using the equation

$$b = \frac{\sum xy - N \bar{x} \bar{y}}{\sum x^2 - N (\bar{x})^2}$$

where, b represents the fraction of added P, which remained available under the condition of the experiment. Added P, released P and number of concentrations of P added (10) are represented by x , y and N respectively. The method is based on the relationship between available P (*i.e.* estimated P) and added P, which is virtually linear and therefore the slope of the curve relating released P (y -axis) and added P (x -axis) was calculated out by the standard equation mentioned above. The percent of P-fixation of added P is thus given by

$$\text{Phosphate fixation capacity (\%)}, P = 100 - b \times 100$$

Table 1. (a) Physico chemical characteristics of the experimental soil; (b) Mechanical composition of the soil (in %).

(a)				
Parameters	Values			
Physical characteristics:				
Particle density (g/cc)	2.49			
Bulk density (g/cc)	1.33			
Water holding capacity (%)	23.1			
Chemical characteristics:				
pH	5.4			
Organic Carbon (%)	0.52			
Total Nitrogen (%)	0.059			
Available Nitrogen (kg/ha)	135.0			
Available P (kg/ha)	5.6			
Available K (kg/ha)	89.5			
Cation Exchange Capacity (me/100g)	10.19			
Aluminium Oxide (%)	17.2			
Iron Oxide (%)	1.60			
(b)				
Sand		Silt	Clay	Textural class
Fine	Coarse			
27.4	33.8	11.9	26.9	Sandy Clay Loam

4. RESULTS AND DISCUSSION

The P-fixing capacity of a soil can be drawn from the relationship of added phosphorus and extracted available phosphorus on addition of graded quantum of phosphorus, after a time interval, in a particular soil. The data on addition of graded amount of inorganic phosphorus (**Table 2**) at both the soil depth indicated that the relationship between available and added phosphorus was virtually linear (**Figure 1**). This was in accordance with the findings of Nad *et al.* (1975). Thus the slope “*b*”, which is the fraction of the added phosphorus remaining available under the conditions of the experiment, was calculated using the formula mentioned above and the values were 0.404 and 0.351 for soils from 0 - 20 cm and 20 - 50 cm depths respectively. The percent fixation of phosphorus in the soil came out to 59.60% and 64.94% for the surface and subsurface soil respectively. The P-fixing values were close to that of the lateritic soil at Mangalore having pH 5.6. It may be noted that the subsurface soil has higher P-fixing capacity than the surface soil. This may be attributed to lower phosphorus content in the subsurface as well as presence of more organic matter in the surface as compared to subsurface soil. Organic matter on decomposition releases organic molecules, which form complexes with Fe and Al ions thereby blocking the sites which are mainly responsible for fixation of phosphorus [9-11]. This is supported by results of another experiment [12] conducted in the same site which showed that addition of organic manure markedly increased the availability of phosphorus in the soil. This increase in phosphorus availability in the soil was found to be statistically significant over control treatment and also over treatments with inorganic fertilizers.

Table 2. Available P ($\mu\text{g/g}$), on addition of graded amount of inorganic phosphorus to the soil.

Added P ($\mu\text{g/g}$)	Available P ($\mu\text{g/g}$)	
	0 - 20 cm	20 - 50 cm
0	7.96	5.96
20	16.92	12.96
40	21.56	18.92
60	30.88	25.24
80	44.48	39.56
120	56.44	53.12
160	83.96	77.80
200	97.60	88.96
240	119.52	103.60
300	106.24	100.28

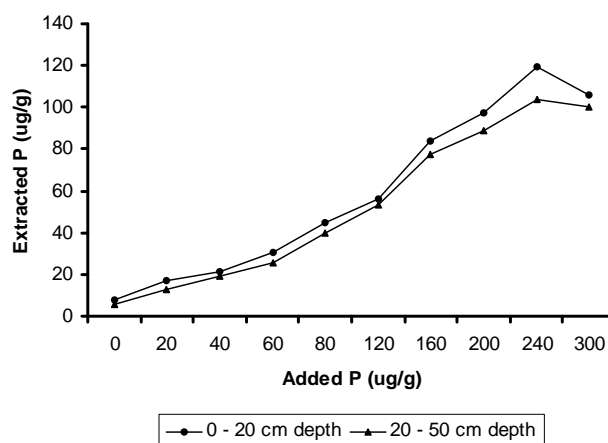


Figure 1. Available P on addition of graded amount of inorganic phosphorus in the soil collected from two depths.

Thus the soil of the eastern plateau area is characterized with low soil available phosphorus and as much as 60% of the applied P can get fixed in the soil. Under such circumstance the P fixation capacity must be overcome by application of fertilizer P at a higher rate or by applying slow releasing P fertilizers as phosphate rocks to have enough P left over for crops to increase productivity.

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