

## Phosphate Isotherms for Some Calcareous Soils

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Phosphate sorption isotherms for some Marathwada soils were determined by equilibrating air dry samples for 24 hours with 0.01 M  $\text{KH}_2\text{PO}_4$  solution at  $25 \pm 1^\circ\text{C}$ . Phosphate sorption capacities of soils were evaluated by using Langmuir and Temkin equations. Phosphate sorption maxima of Parbhani, Ambajogai, Mukhed, Vaijapur and Tuljapur were 1870, 1825, 1695, 1545 and 1620 mg p/kg soil respectively.  $X/\text{Log } C$  (another parameter to represent phosphate sorption capacity for soils) values for the same soils were 816.790, 721, 697 and 633 respectively. Where  $X$  = Phosphate sorbed (mg/kg soil) and  $C$  = Equilibrium phosphate concentration ( $\mu\text{mol/ml}$ ). Sorption in calcareous soils was significantly correlated with organic carbon ( $r = 0.853$ ), clay ( $r = 0.992$ ) and exchangeable calcium and magnesium ( $r = 0.931$ ) contents in the soils. P sorption index ( $X/\text{Log } C$ ) was also positively correlated to the above soil properties.

The efficiency of applied phosphorus in regard to its utilisation by plants is usually very low. The values for recovery of applied phosphorus for most of the soils show a range from 16 to 20 per cent (Goel *et al.* 1960). Soils greatly vary in their phosphate fixing capacities. Sorption of added phosphate in calcareous soils depends on calcium carbonate content and exchangeable cations particularly Ca and Mg. (Larsen and Widdowson, 1970; Kanwar and Grewal, 1960) and on pH, exchangeable aluminium, free iron oxide, organic matter and clay content in acid soils.

Although the method of Piper (1966) based on anion exchange capacity provided useful measurements of phosphate sorption capacity, the exact interpretation of sorption index was not related to physico-chemical parameters. Bache

and Williams (1971) introduced a new phosphate sorption index taking into account the concept of quantity and intensity. The phosphate adsorption isotherm however gives better meaning to characterize soil sorption. The adsorption isotherms have largely been used to determine phosphate buffering capacity of soils.

Black cotton soils of Marathwada are distinctly calcareous in nature and show a greater tendency for phosphate sorption. There is very little published information on phosphate sorption characteristics of black cotton soils of Marathwada. Comparative studies are also lacking to relate sorptive characteristics of these soils to calcium carbonate and exchangeable cations. The present investigation presents a comparative study of P sorption and to relate

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TABLE I. Physico-chemical properties of Marathwada soils

Soils	pH	Organic matter	Mechanical analysis				CaCO <sub>3</sub>	C.E.C.	Ex. Ca M.E. 100g soil	Ex. Mg me./100 g soil
			Coarse sand%	Fine sand%	Silt %	Clay %				
Parbhani	8.25	1.675	2.15	6.34	18.23	69.14	10.5	54.53	32.31	4.27
Ambajogai	8.30	1.861	6.10	18.40	18.75	54.75	10.0	54.92	33.27	4.10
Mukhed	8.55	1.241	1.60	13.14	37.50	35.00	11.5	48.51	28.75	5.53
Vaijapur	8.55	1.427	6.17	25.62	35.75	26.25	7.5	46.72	25.35	4.00
Tuljapur	8.70	0.930	24.65	35.65	15.00	18.00	7.0	34.11	14.63	3.95

sorption capacity of soils with some soil factors and to evaluate Langmuir and Temkin equations for sorption index of soils.

#### MATERIAL AND METHODS

The soil samples collected from 0-20 cm depth represented a wide range of soil types covering vast area in Marathwada.

Parbhani soil having 69.1 per cent clay, is deep black calcareous vertisol. Ambajogai soil has sandy clay loam texture. Mukhed soil has 35.0 per cent clay and is shallow medium black soil. Vaijapur soil with 26.2 per cent clay and Tuljapur soil sandy loam in texture (18.0 per cent clay) are pale brown in colour. Physio-chemical properties of these soils are presented in Table I.

**Laboratory study:** Five gram air-dried soil samples ground to pass a 0.2 mm sieve (IMM 60 Mesh) were weighed in duplicate into 250 ml conical flasks. A 0.01 M solution of  $\text{KH}_2\text{PO}_4$  in 0.01 M KCl was added to each flask in amounts varying from 0 to 50 ml giving phosphate additions of 0.3100 mg P/Kg soil and the volume made upto 100 ml with 0.02 M KCl to maintain approxi-

mately constant ionic strength of 0.02. Three drops of toluene were added to inhibit microbial activity and the flask stoppered and continuously shaken at  $25 \pm 1^\circ \text{C}$  on a reciprocating shaker for hour. The suspensions were passed through Whatman No. 42 filter paper to eliminate organic debris and the filtrate was centrifuged. Phosphate concentration in supernatant was determined colorimetrically (Olsen *et al.* 1954) and the phosphate sorbed was calculated by difference.

Soil pH was determined in 1:2.5 soil water suspension organic carbon by dichromate oxidation (Walkely and Black, 1934), acid ammonium oxalate extractable sesquioxides were determined by shaking 1 g soil sample with 100 ml ammonium oxalate (pH 3.0) for four hours. Fe in solution was determined by colorimetrically as O-phenanthroline red ferrous complex (Jackson 1967); Free calcium carbonate was determined by rapid titration method (Piper, 1966). Exchangeable calcium and magnesium were determined by the methods outlined by Piper (1966).

TABLE II. Phosphate sorption characteristics of Marathwada soils

Soils	Langmuir adsorption maxima (mg/kg soil)	Range of linearity of langmuir plot/t mol/ml	P sorbed form 620 mg P/Kg soil %	Temkin X/Log C (X=mg/kg C=m mol/ml.)	Organic carbon	Fe m mol/Fe 100 g soil.	Al m mol Al/100 g soil	Ex. Ca +Mg m. e./ 100 g soil
Ferbhani	1870	0.56	95.2	816	0.97	0.337	24.67	36.6
Ambajogai	1825	0.60	91.9	790	1.08	0.287	20.80	37.4
Mukhed	1695	0.66	87.9	721	0.72	0.175	26.16	34.1
Vaijapur	1645	0.70	86.2	697	0.82	0.237	18.47	29.4
Tuljapur	1620	0.75	82.2	683	0.54	0.249	18.56	18.6

## RESULTS AND DISCUSSION

Statistical correlations between phosphate sorption and other soil properties were worked out to recognize which of the soil components actually contributed to phosphate sorption. Variations in CEC and clay content among the soils are quite distinguishable. Parbhani and Ambajogai soils are clayey with relatively higher proportion of CEC (54.53 and 54.92 me/100 g soil) and exchangeable calcium. Tuljapur soil has only 18 per cent of clay.

The phosphate sorption characteristics of the soils were studied by adsorption equations of Langmuir and Temkin equations. The Langmuir equation is based on the assumption that the energy of adsorption does not vary with the surface coverage and is written as

$$\frac{C}{X} = \frac{C}{X_m} + \frac{1}{KX_m}$$

Where C = equilibrium phosphate concentration and X = weight of phosphate adsorbed per unit weight of soil. The resulting isotherms appeared to reach

maximum at higher concentrations, however, the sorption continued to increase gradually with increasing amounts of phosphate added to soil suspension without well defined adsorption maxima. Adsorption maximum for each of the soil was calculated from the equation (Table II). Parbhani soil showed the highest adsorption maximum of 1870 mg P/Kg soil, while maximum adsorption of phosphorus in Tuljapur soil was 1620 mg P/Kg soil. Linearity was greater with Tuljapur soil which incidentally exhibited lower P adsorption compared to other soils. About 95.2 per cent of phosphorus was adsorbed from 620 mg P applied to Parbhani soil whereas Tuljapur soil retained about 82.2 per cent of phosphorus from the same amount. The phosphate sorption capacities of calcareous soils of Marathwada seemed to be higher. Kanwar and Grewal (1960) reported 70.3 per cent phosphate retention in calcareous soils of Punjab. Weir (1972) and Syers *et al.* (1973) also observed similar pattern of P adsorption.

Temkin equation presupposes the condition that the energy of adsorp-

tion decreases linearly with increasing surface coverage. The equation is

$$\frac{X}{X_m} = \frac{RT}{b} \ln AC$$

Where A and b are constants. A plot of X against log C should give a straight line. Bache and Williams (1971) suggested the use of X/log C as a suitable index to characterize the phosphate sorbing properties of soils. The non-linearity of isotherms indicated more than one kind of absorbing surfaces involved in P retention in these soils. X/log C values where X = P sorbed mg/Kg soil and C equilibrium concentration  $\mu$  mol/ml for the soils studied varied greatly. Parbhani soil showed maximum X/log C values of 816 indicating higher P adsorption capacity. Greater P sorption capacity of Parbhani soil also has been observed in Langmuir relationship earlier. X/log C and adsorption maxima ( $X_m$ ) for the soils studied were directly related to each other. Ambajogai, Mukhed, Vaijapur and Tuljapur showed 790, 721, 697 and 683 values for X/log C parameter (Table II). P sorption capacities of soils represented as X/log C values provided better index for the reason that it (X/log C values) incorporated meaning for intensity factor which is of fundamental importance in soil phosphate studies.

**Soil factors related to phosphate sorption:** The relationship between different soil properties and P sorption capacity expressed in  $X_m$  (adsorption maxima) and X/log C values is presented in Table III. Among the properties, organic carbon, clay content and

TABLE III. Relationship between Soil properties and phosphate sorption in Marathwada soils.

Variables	P sorption Capacity $X_m$	P. Sorption index $X/\log C$
pH	-0.976*	-0.976*
Organic carbon	0.853	0.854*
Fe	0.730	0.737
Al	0.507	0.500
Clay	0.992*	0.993*
CaCO <sub>3</sub>	0.649	0.639
Ex Ca+Mg	0.931*	0.923*

(\* Significant at P=0.01)

exchangeable calcium and magnesium content of soils were found to be positively significantly (P=0.01) related to phosphate retention or sorption. Clay content of soils affected (r=0.99) most the P sorption properties of soils. Parbhani soil with higher clay content (69.14 per cent) showed greatest P sorption (95.2 per cent of added phosphate). While Tuljapur with 18 per cent clay accounted 82 per cent sorption of added phosphate. Exchangeable calcium and magnesium content of soils also contributed to P sorption characteristics of soils. Calcareous soils of Marathwada have Ca and Mg as dominant cations or exchange sites (Table II). It is not surprising P sorption being influenced in these soils by these cations. Similar relationship between P sorption of added phosphate and exchangeable cations particularly calcium and magnesium has also been reported by Kanwar and Grewal (1960) and Larson and Widdowson (1970).

Organic carbon or organic matter in the soil also influenced P sorption capa-

city of soils ( $r=0.85$ ). Positive correlation between organic matter and P sorption of added phosphates have been reported by Williams (1960) Saini and McLean (1965) for temperate conditions and by Ahenkorah (1968) and Lopez-Hernandez and Burnham (1974) in tropical soils. It has been suggested that phosphate added to soil reacts immediately with soil organic matter in some kind of anion exchange reaction (Harter 1969).

From the results on P sorption of added phosphate to calcareous soils, it is observed that P sorption capacity or characteristics of soil very much depended on soil properties and appeared to be a complex phenomenon. It is rather difficult to predict maximum P adsorption capacity of soils since P sorption continued to increase though gradually even at very high concentration. Moreover more than one adsorptive surface/soil factors are involved in P sorption.

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