https://doi.org/10.29321/MAJ.10.A03109

Madras agric. J. 65 (8): 513–519, Aug., 1978.

Phosphate Adsorption Characteristics of Tamil Nadu Soils

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Phosphate adsorption isotherms were studied for twenty soils representing four major soil groups viz., red, black, alluvial and laterite. The P adsorption capacities of the soils varied widely and the P adsorption was high in high level laterite soils. The P adsorption isotherms were found to fit Langmuir's equation at equilibrium concentration of less than 5 ppm. P adsorption maximum of these soils ranged from 118 to 1750 $\mu g/g$ of soil. P adsorption maximum positively correlated with total R_2O_3, Al_2O_3, Fe_2O_3 Free Fe_2O_3, silt, organic carbon and clay. P adsorption maximum was found to have a negative relationship with soil pH.

Phosphate adsorption is usually defined as the tendency for P ions to concentrate at the interface between the liquid and solid phases of the soil system. The reaction of fertilizer P with soils depends upon the nature and amount of adsorbing surface as well as pH and other factors. The Langmuir equation has been used to describe the adsorption of P by soils (Gunary, 1970). Olsen and Watanabe (1957) showed that the adsorption of P by soils from dilute solutions showed a closer agreement with the Langmuir isotherm than the Freundlich isotherm. P adsorption properties of Tamil Nadu soils and their utility to predict the fertilizer needs have not been studied in detail. The P adsorption isotherms to measure the availability of phosphorus is gaining greater importance in soil fertility studies and with this object in view, the present investigation was undertaken to study the phosphate adsorption characteristics of major soil groups of Tamil Nadu.

MATERIALS AND METHODS

Twenty surface (0-15 cm) soils belonging to the four groups of soils viz., red, black, alluvial and laterite were used for the study. Mechanical analysis of the soils was done by International Pipette method and organic carbon as described by Piper (1966). Total sesquioxides, Fe_2O_3 were estimated by standard procedures. Free Fe_2O_3 was estimated by the method of Coffin (1963) as described by Hesse (1971). The pH of the soil was estimated with Beckman pH meter in a soil water suspension of 1 : 2 ratio. Soil samples weighing 1.5 g crushed to pass through 1 mm sieve were shaken for one hour twice daily with 30 ml of

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0.01 M $CaCl_2$ solution containing various amounts of P as KH_2PO_4 in 50 ml centrifuge tubes for 6 days. Equilibration period was based on the earlier study (Rajan and Fox, 1972). The tubes were centrifuged for 15 minutes at 2500 RPM x G and P was estimated in the supernatant solution by the molybdenum blue method. P removed from the solution during equilibration was considered to have been adsorbed.

The isotherm data were analysed employing Langmuir's adsorption equation

$$\frac{C}{x/m} = \frac{1}{ab} + \frac{C}{b}$$

Where C = equilibrium P concentration (μg/ml)

x/m = μg of P adsorbed per g of soil

b = P adsorption maximum

a = constant related to P bonding strength of soils

The reciprocal of the slope was calculated to obtain the P adsorption maximum.

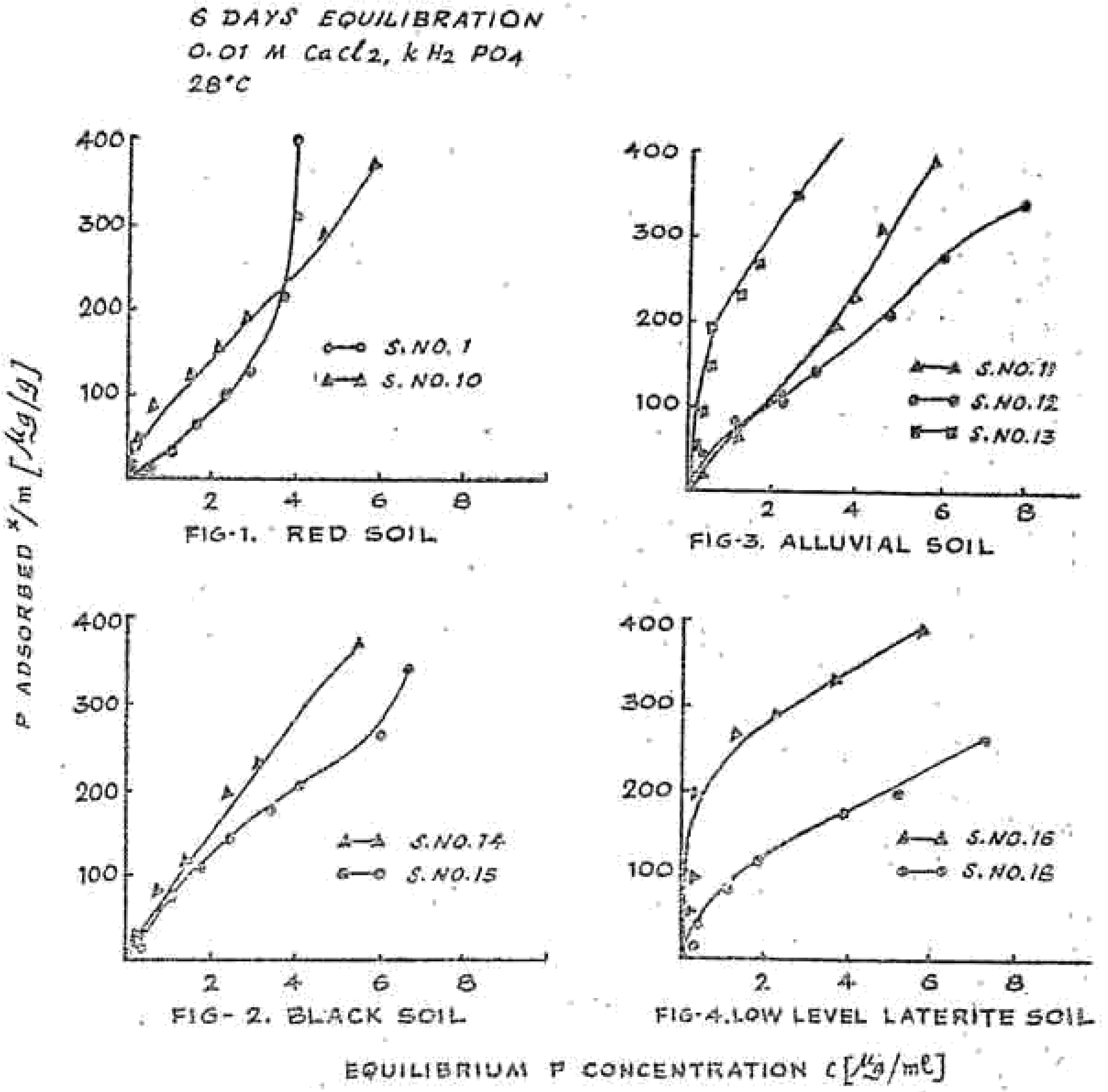
RESULTS AND DISCUSSION

The general physico-chemical properties and P adsorption maximum for twenty soils are given in Table I. The P adsorption isotherms drawn for nine soils viz., red soils (Nos. 1 and 10), black soils (Nos. 14 and 15), alluvial soils (Nos. 11, 12 and 13) and low level laterite soils (Nos. 16 and 18) are shown in figures 1, 2, 3 and 4. There was a wide variation in the adsorption characteristics of different soils. Isotherms with steep and flat curves indicated the soils having high and low P adsorption capacities respectively. High level laterite soils of Ootacamund and Coonoor had the highest adsorption of P at any concentration in the equilibrium solution. Both these high level laterite soils are highly weathered compared to other soils and they behaved similarly in most of the soil properties. The high adsorption capacity of the high level laterite soils can be attributed to the enormous specific surface of highly reactive hydrated iron and aluminium oxides of these soils. Among the red soils, Vellalur soil had high adsorption capacities compared to other red soils. In black soils, Peelamedu soil had higher P adsorption capacity than the Kovilpatti soil. Low level laterite soils of Vallam and Mudukulam adsorbed more P than Pattukottai soil. Among the alluvial soils, Aduthurai soil had the highest adsorption at any concentration in the equilibrium solution, while Koduveri and Noyyal adsorbed the least. Generally, the high level laterite soils showed higher adsorptive power than low level laterite and other soils. This may be attributed to the presence of high amount of total sesquioxides, free oxides of Fe and organic matter content. Soundararajan (1971) stated that the capacity of the soil to adsorb P was related to their mineralogy. The order of increasing adsorption was 2:1 clay, 1:1 clay and oxides. Syers *et al* (1973) reported that the ability of soils to sorb added P increased with increase in clay content, exchangeable Al, citrate dithionate soluble Fe and Al. The present study confirms the earlier observations. The high level laterite soils of Nilgiris contained higher amount of hydrated oxides of Fe and Al and kaolinite as dominant clay mineral (Rama-

TABLE I. Soil Physico-Chemical Properties and P Adsorption Maximum

Location	Major soil group	Soil reaction	Slit (%)	Clay (%)	Sesqui-oxides (%)	Iron oxide (%)	Alumi-nium oxide (%)	Free iron oxide (%)	Loss on igni-tion (%)	Orga-nic carbon (%)	P adso-rption max. µ/g
Irugur	Red	7.1	2.95	19.83	11.81	2.85	8.96	1.46	4.88	0.99	333
Palathurai	Red	7.7	1.93	14.43	11.69	4.86	6.84	1.86	4.27	1.91	181
Ammapettai	Red	7.8	12.50	50.75	8.36	3.65	4.72	0.79	3.59	0.39	261
Chickarasampalayam	Red	7.4	11.18	31.17	11.59	4.42	7.16	2.92	6.83	0.57	167
Kuppandampalayam	Red	7.5	4.78	19.28	14.22	4.55	9.67	0.53	4.83	0.72	235
Pichanur	Red	7.4	1.68	11.25	8.97	3.55	5.42	0.44	2.72	1.32	333
Satyamangalam	Red	7.9	5.80	27.68	12.88	6.51	6.37	1.64	4.50	0.54	250
Vellalur	Red	7.8	12.50	50.75	9.52	4.58	4.94	2.04	8.73	1.08	667
Anaimalai	Red	7.1	2.10	6.05	7.31	4.50	2.81	1.64	1.31	0.63	118
Palathurai	Red	7.7	2.70	14.70	11.69	4.86	6.84	0.93	4.27	1.91	181
Noyyal	Alluvial	6.6	6.20	15.53	9.35	2.99	6.36	1.42	4.54	2.64	118
Koduveri	Alluvial	7.7	12.83	27.18	13.84	5.31	8.03	1.73	7.93	1.56	143
Aduthurai	Alluvial	7.2	2.89	51.72	19.01	5.47	13.54	0.65	7.64	0.72	333
Peelamedu	Black	7.7	8.25	41.50	15.92	3.75	12.16	—	12.85	1.14	667
Kovilpatti	Black	8.1	3.60	58.05	3.25	0.85	2.40	0.19	8.59	0.20	286
Vallam	Laterite	5.0	23.77	43.58	24.58	5.94	18.64	0.53	5.52	0.35	333
Mudukulam	Laterite	5.9	1.41	25.85	14.00	2.82	11.18	0.65	3.70	0.33	333
Pattukottai	Laterite	5.4	0.25	17.27	6.14	1.77	4.37	0.68	2.44	0.38	200
Ootacamund	Laterite	5.4	29.38	51.81	37.21	11.26	25.95	0.80	16.30	2.70	1750
Coonoor	Laterite	5.5	20.18	41.36	36.63	12.25	24.38	1.24	15.51	2.40	1700

PHOSPHATE ADSORPTION ISOTHERMS



nathan, 1974) and hence these soils had higher adsorptive power than other soils.

The adsorption data plotted according to the Langmuir equation for red soil (S.Nos. 3, 6 and 9), black soil (S.Nos. 14 and 15), alluvial soil (S.Nos. 12 and 13) and low level laterite soils (S.Nos. 16 and 18) are presented in figures 5, 6, 7 and 8 respectively. It was observed that the initial portion of the graph was linear in all cases but abrupt breaks were found except in Vallalur red soil. The deviation occurred in most of the soils was between two and four ppm equilibrium solution. The isotherms were found to fit Langmuir equation at equilibrium concentration of less than five ppm as observed by Soundararajan (1971) for Tamil Nadu soils. The black soil of Peelamedu and red soil of Vellalur behaved entirely different from other soils. The adsorp-

THE LANGMUIR PLOT OF P ADSORPTION ISOTHERMS

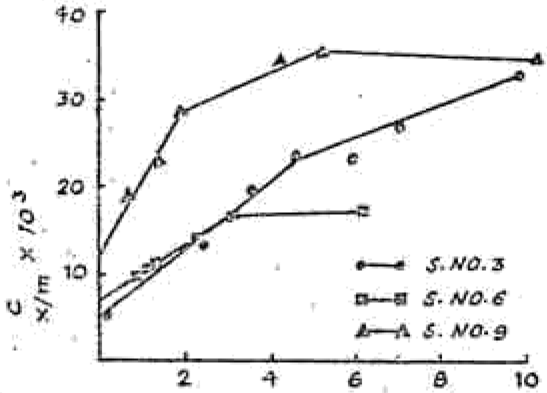


FIG-5. c[µg/ml] RED SOIL

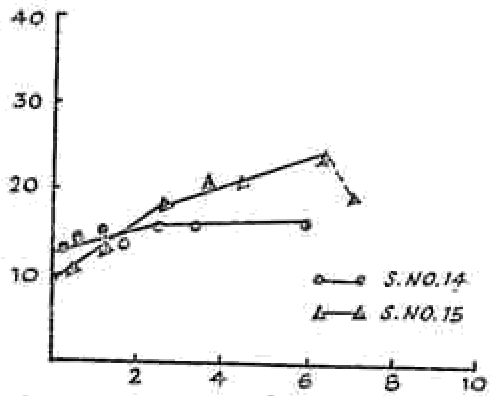


FIG-6. c[µg/ml] BLACK SOIL

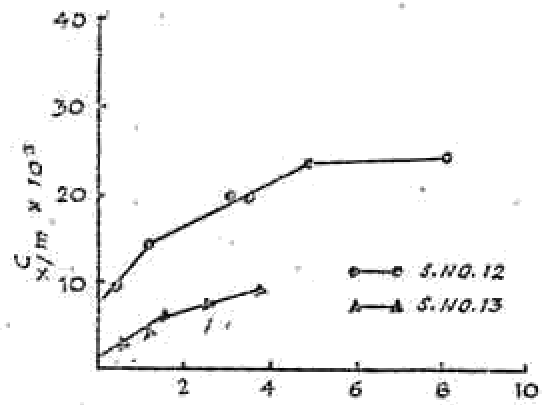


FIG-7. c[µg/ml] ALLUVIAL SOIL

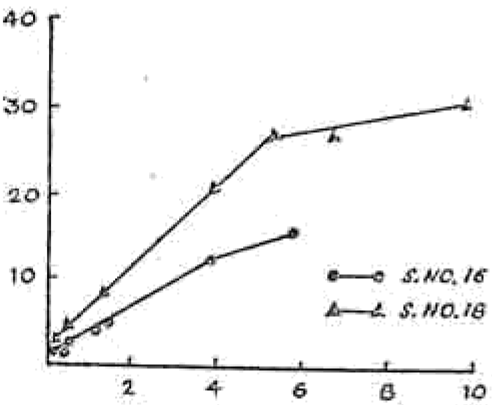


FIG-8. c[µg/ml] LOW LEVEL LATERITE SOIL

tion data did not however, confirm with Langmuir isotherm at higher concentrations. Such deviations were also observed by Olsen and Watanabe (1957), Gunary (1970), Soundararajan (1971) and Udo and Uzu (1972). Since the Langmuir's equation is based on a monolayer adsorption of the adsorbents, Gunary (1970) explained the deviations at high concentrations on continued adsorption of P after the monolayer adsorption had been achieved on adsorption sites. The black soil of Peelamedu and red soil of Vellalur behaved entirely different from other soils. Such a behaviour of these soils might probably be due to their calcareous nature which greatly influence retentive capacity of P.

Phosphate Adsorption Maximum : The phosphate adsorption maximum values of soils ranged from 118 to 1750 µg/g. The highest value of 1950 µg/g of soil was recorded in the high level laterite of Ootacamund and Coonoor and the lowest in red soil of Anamalai (118 µg/g of soil). A notable feature was that P adsorption maximum of high level laterite soils was four to 15 times greater than other soils. There was not much difference in the P adsorption maximum values in case of red and black soils though Peelamedu black

TABLE II. Results of Statistical analysis for correlations between P adsorption maximum and other soil properties

Variable Y	Correlation Co-efficients (r)	Regression equation	No. of pairs
Total sesquioxides	0.850**	$\hat{Y}$: 45.264X — 228.10	20
Iron oxide	0.817**	$\hat{Y}$: 142.388X — 268.64	20
Aluminium oxide	0.818**	$\hat{Y}$: 59.348X — 142.30	20
Free iron oxide	0.717**	$\hat{Y}$: 270.648X — 35.74	20
Organic carbon	0.532*	$\hat{Y}$: 316.399X + 68.02	20
Loss on ignition	0.859**	$\hat{Y}$: 97.278X — 218.12	20
pH	−0.474*	$\hat{Y}$: 229.059X + 2025.92	20
Clay	0.480*	$\hat{Y}$: 14.091X — 12.99	20
Silt	0.712*	$\hat{Y}$: 270.648X — 35.74	20

* Significant at 5 per cent level

** Significant at 1 per cent level

soil had higher value than the above said soils. Between low level laterite soils, Vallam and Mudukulam had slightly higher adsorption than Pattukottai soil. Among the alluvial soils, Aduthurai soil was high in P adsorption maximum compared to Noyyal and Koduveri soils.

The relationship of P adsorption maximum with soil characteristics is given in Table II. P adsorption maximum correlated significantly with total sesquioxides (r = 0.850**), Fe_2O_3 (r = 0.817**), Al_2O_3 (r = 0.818**) and free oxides of Fe (r = 0.717**). Similar correlations were obtained by Vijayachandran (1966) in laterite soils of South India. It has been well established that the oxides of iron and aluminium are largely responsible for adsorption of P in acid soils (Hinga, 1973).

High correlations with free oxides of Fe (citrate dithionate soluble) was obtained (r = 0.717**) thereby indicating that iron is more important in the adsorption of P in the soils studied. P adsorption maximum correlated significantly with clay content (r = 0.480*) and negatively correlated with pH (r = -0.474*)as reported by John(1972) and also Udo and Uzu (1972). The silt, loss on ignition and organic carbon were found to correlate with P adsorption maximum, the r values being 0.712**,

).859** and 0.532* respectively. The lose relationship of organic carbon vith P adsorption maximum is understandable since organic matter might rovide major sites for P adsorption John, 1972; Hinga, 1973). The results f the present study have shown that he total sesquioxides, Fe_2O_3, Al_2O_3, ree oxide of Fe, organic carbon, clay, pH and silt content of the soils were mainly responsible for P adsorption in these soils.

The senior author is grateful to the Tamil Nadu Agricultural University for according permission to publish data which formed part of M.Sc. (Ag.) thesis.

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