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Application of Freundlich Adsorption Isotherm to Determine Phosphorus Requirement of Several Rice Soils

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ABSTRACT

Freundlich sorption isotherms were used to evaluate the P requirement of 11 rice soils in a lab study. The soils were medium to heavy textured, alkaline in reaction and were highly calcareous. Amount of P sorbed by the soils increased with increasing P in equilibrium solution. Quantities of P retained on sod solid phase were significantly correlated ($p<0.05$) with clay and free lime content of the soils. Maximum P was sorbed by a soil (Jatput) that had the maximum (14%) $CaCO_3$ content.

Key Words: Freundlich sorption isotherms; Rice soils; Graded doses of P

INTRODUCTION

Phosphorus deficiency is very common on alkaline calcareous soils and majority of soils under rice in Pakistan are deficient in it (NFDC, 1988). Soils on which, rice is grown in Pakistan vary in their degree of calcareousness, hence P deficiency and its requirement on these soils will vary for rice and upland crops following rice. Routine soil tests used to delineate P deficiency and estimate its availability in sod can segregate from responsive to non-responsive soils (MacLean, 1978). They have limited value for quantifying of fertilizers required for specific crops for diverse sod conditions.

Beckwith (1964) suggested phosphorus sorption as one of the more promising technique for measuring both the intensity and capacity factor of soils for P. He suggested standard concentration of 0.2 mg kg^{-1} phosphorus in solution to compare P sorption by soils because it is the adequate concentration of P in solution for most crop species. This has been successfully used to determine P requirement of several soils (upland) for optimum crop yield (Fox & Kamprath, 1970; Fox, 1981). Fox (1981) estimated the requirements from P sorption curves and correlated with P requirements established by field experiments and were highly correlated.

Use of P sorption isotherms for determining P requirements, provides also useful information regarding P use efficiency. Their use can result in reduction as well as increased efficiency of P Certification, because the method takes into account the soils ability to sorbs P as well as to maintain P concentration in solution. Therefore, the amount of P fertilizer applied that required to maintain P concentration in solution needed for proper growth of crops will be minimum. Information about P sorption isotherms of our soils especially under rice is quite lacking. Present paper discusses the utilization of Freundlich adsorption isotherm to determine P requirement of several irrigated rice soils.

MATERIALS AND METHODS

Bulk surface samples (0-15 cm) collected from 11 major rice soils of Pakistan were air dried and ground to pass through a 2 mm sieve. The samples were characterized for pertinent physicochemical properties according to standard procedures (Richards, 1954).

Duplicate 2.5 g portion of each soil was shaken on a reciprocating shaker for 24 hours at 25±2°C with 25 mi of 0.01 M $CaCl_2$, containing graded levels of P ranging from 2.5 to 40 ug P ml^{-1} as KH_2PO_4. Soil: Solution ratio was 1:10. Two to three drops of toluene were also added to soil: solution suspension to check against microbial growth. After equilibration, sod solution was separated by centrifugation and filtration of the sod suspension. Phosphorus in equilibrium solution was determined by Vanado-molybdate blue color method (Watanabe & Olsen, 1965). Amount of P sorbed by various soils was calculated as difference between initial and final concentrations of P in equilibrium solution (Patrick & Khalid, 1974). For determining P requirement of individual soils the sorption data were fitted to Freundlich equation given below:

$X = ac/^{ln}$

Where X is ug of P sorbed per g of so@ c is equilibrium P (ug ml^{-1}), and "a" and "n" are constants. Linear plot of log X versus log c yields "a" as intercept and "n" as slope (Roy & Detta, 1985).

RESULTS AND DISCUSSION

Physico-chemical characteristics of the soils under investigation are given in Table I. Soils textures were sandy loam to sandy clay loam with clay content ranging from 20.8 to 36%. Soils were mostly alkaline with pH ranging from 7.9 to 8.6. These were calcareous with lime ranging from 6.41 to 14.3%. Soils were low in organic matter and it ranged from 0.51 to 0.62%.

The amount of P adsorbed by the 11 soils increased with increasing P concentration in equilibrium solution (Table II). Jatput soil series adsorbed the maximum phosphorus. Higher clay and lime content of Jatput soil series seems to be responsible for greater adsorption of P as compared to other soils. Several other investigators have also reported such results (Vig & Dev, 1978; Dhillon & Dhillon, 1984).

Gaikawad and Patrik (1969) observed that P adsorption followed the Freundlich equation in rice soils belonging to different ecological zones. Hence, sorption of P by rice soils used in the present study was best explained by the Freundlich equation. Various slopes and intercept values calculated for the Freundlich isotherms are reported in Table III. The slope and intercept values ranged from 0.94 to 1.24 and 1.44 to 1.78.

Eleven soils used in this study were similar in their P sorption characteristics, since they all had high clay content and were highly calcareous. Value calculated for slope significantly correlated with clay as well as free lime content in the eleven soils (Table IV). Available phosphorus as estimated by N_aHCO_3, according to Olsen's method ranged from 4.73 to 10.1 mg kg-[1] that was not highly deficient. Intercept values calculated for logarithmic form of Freundlich isotherm can be considered as equilibrium P available

Table I. Selected characteristics of soils

Soils	Taxonomical nomenclature	Textura l class	Silt (%)	Clay (%)	Sand (%)	$CaCO_3$ (%)	Organic carbon (%)	PH	Olsen P (Mg kg^{-1})
Marghzar	Typic AricHapluquept	SCL	16.2	33.1	50.70	12.60	0.51	8.30	5.39
Gujranwala	UdicHaplustalf	-do-	17.3	33.8	48.90	13.01	0.55	8.20	4.98
Kotly	Entic Chromostert	-do-	14.8	30.5	54.90	11.36	0.57	8.40	6.23
Kamonke	Typic Ustochrept	-do-	12.3	26.5	61.20	09.31	0.60	8.50	7.79
Satghara	Typic Natargid	-do-	14.0	26.9	59.20	09.51	0.58	8.40	7.64
Shahpur	Fluventic Camborthids	-do-	16.0	23.7	60.30	07.86	0.51	8.10	8.89
Miranpur	Ustic Camborthids	-do-	17.4	30.8	51.80	11.49	0.54	8.20	6.14
Jatput	Entric Chromoderts	-do-	20.0	36.0	44.00	14.30	0.62	8.60	4.20
Gujiana	Ustaffic Camborthids	SL	20.0	20.8	59.20	06.41	0.58	8.20	10.10
Dara	Aquic Camborthids	Sci	18.0	31.8	50.20	12.02	0.52	7.90	5.70
Gungro	Fluventic Cambordids	-do-	16.0	35.0	49.00	13.34	0.54	8.10	4.73

SCL= Silty Clay Loam; SL= Silty Loam

Table II. Phosphorus Sorption (ug g^4) of Soil at Different Initial P Concentration (ugml^4)

Soils	Taxonomical nomenclature	Initial P Concentration ugml^{-1}					
		2.5	5.0	10.0	20.0	30.0	40.0
Marghzar	Typic Aeric Hapluquept	21.1	43.5	87.0	175.0	258.7	345.0
Gujranwala	Udic Haplustalf	21.1	43.6	87.0	175.0	259.1	345.5
Kotly	Entic Cliromostert	21.4	43.0	86.0	163.1	254.2	343.0
Kamonke	Typic Ustochrept	21.0	42.0	84.6	163.2	250.0	339.9
Satghara	Typic Natargid	20.8	40.0	80.4	162.2	249.8	340.2
Shahpur	Fluvcntic Camborthids	19.4	37.8	79.9	159.5	243.1	337.7
Nkanpur	Ustic Camborthids	21.4	44.0	87.5	175.0	258.8	343.2
Jatput	Entric Chromod"	20.5	43.5	86.5	173.5	256.3	347.2
Gujiana	Ustaffic Camborthids	18.5	36.5	75.5	157.5	242.2	335.5
Dara	Aquic Camborthids	20.5	43.5	94.6	167.5	250.2	344.0
Gungro	Fluventic Camborthids	21.2	41.2	84.6	167.5	250	346.4

Table III. Phosphorus Requirement of Soil For 0.2 ppm P In Solution by Using slop and Intercept Values Calculated for Linear Form of Freundlich Adsorption Isotherms

Soils	Taxonomical	Intercept	Slop	Regression.	P. required to obtain 0.2 ppm P in

	Nomenclature			Coefficient (R)	soil solution
Gujranwala	Udic Haplustalf	1.78	0.99	0.98	53.43
Kotly	Entic Chromostert	1.76	0.95	0.99	51.31
Kamonke	Typic Ustochrept	1.72	0.99	0.99	45.65
Satghara	Typic Natargid	1.65	1.04	0.99	37.00
Shahpur	Fluventic Camborthids	1.54	1.16	0.99	24.57
Nkanpur	Usturtic Camborthids	1.80	0.94	0.98	57.01
Jatput	Entric Chromoderts	1.74	0.99	0.97	48.12
Gujiana	Ustalfic Camborthids	1.44	1.24	0.99	15.40
Dara	Aquic Cambo~	1.67	0.97	0.96	40.25
Gungro	Fluventic Cafnborthids	1.68	1.01	0.96	40.71

Table IV. Correlation Coefficient between Regression Coefficient and Some Selected Soil Characteristics

Parameter	Intercept	Slope	Clay %	CaCO,	Olsen P
Intercept	–	–	–	–	–
Slope	0.85**	–	–	–	–
Clay %	0.764**	7.93*	–	–	–
Lime %	0.753**	0.796*	0.999***	–	–
Olsen P	0.762^{ns}	0.807^{ns}	0.999***	0.999**	–

for plant uptake, but it could not correlate with P estimated by N_aHCO_3-Olsen`s method. For a number of plant species growing in solution 0.2 mg P kg " in equilibrium solution has been suggested by Beckwith (1964) as a standard for comparative purpose. For 0.2 mg kg" equilibrium soil solution concentration of predicted P according to the regression equation calculated for logarithmic form of Freundlich isotherm for individual soil solid phase P was 15.40 mg kg^{-1} for Gujiana and 57.1 mg kg" for 1\liranpur sod series. Gujiana sod had the highest amount of Olsen's P among eleven sods used in this study. Soil with the highest amount of free lime (Marghzar and Gujranwala) required the highest amount of P on solid phase for 0.2 mg P kg^{-1} in equilibrium solution (Fig. 1).

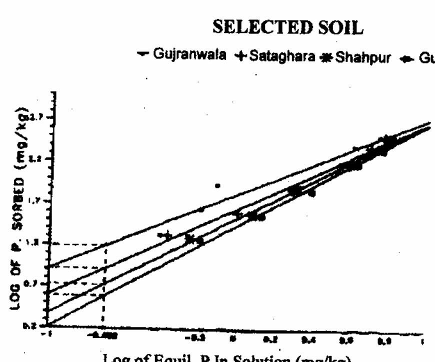

Fig. 1 External phosphorus requirement of four Selected Rice Soils

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