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Determining of Soil Phosphorus Requirement with Application of Freundlich Adsorption Isotherm

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Abstract: Phosphorus (p) adsorption characteristics of 5 soil samples were studied in soils of Southeastern Iran during 2009/2010 cropping season. Some soil properties as well as selected P-adoption characteristics were studied in these soils, Results show for this study Freundlich adsorption isotherm has good match with phosphorus adsorbed data and has good R-square. Freundlich sorption isotherms were used to evaluate the P requirement of 5 soils in a lab study. The soils were medium to heavy textured, acidic 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 content of the soils. Maximum P was sorbed by a soil that had the maximum (64%) Clay content. there were negative relationship between P adsorption capacity and SOC and Ca content of soils.

Key words: Freundlich, sorption isotherms, phosphorus, heavy textured, soil

INTRODUCTION

Phosphorus deficiency is very common on alkaline calcareous soils and majority of soils (NFDC, 1988). Soils on which, wheat is grown in Iran vary in their degree of calcareousness, hence P deficiency and its requirement on these soils will vary for wheat and upland crops following wheat. Routine soil tests used to delineate P deficiency and estimate its availability in sod can segregate from responsive to non-responsive soils (McLean, 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. Beckwith (1964) 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 and 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.

Man's land use activities affect global P-cycle. If p is applied to soil in excess of crop requirement, P will generally build up in the soil (Zhang *et al*., 2005). 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

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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 wheat is quite lacking. Present paper discusses the utilization of Freundlich adsorption isotherm to determine P requirement of several irrigated wheat soils. Phosphorus is a critical element in natural and agricultural ecosystems throughout the world (Onweremadu, 2007) as its limited availability is often the main constraint for plant growth in highly weathered soils of the tropics (Bunemann *et al*., 2004). Phosphorus deficiency problems are common in well-weathered oxisols and ultisols because of strong acidic reactions and abundance of Al and Fe ions (Saleque *et al*., 2004) and the situation can be worsened with inappropriate P management (Saleque *et al*., 1998) Rice removed about 2 to 3 kg P for 1 mg of grain produced (Timsina and Connor, 2001). All these show that P-availability and use by plants vary among plants. We hypothesize that P-availability and uptake relate to sorption characteristics of soil. Based on the above, the major objective of this study was to investigate P-sorption characteristics as influenced by Land Utilization Type (LUT).

MATERIALS AND METHODS

The research was carried out during the 2009/2010 cropping season at omidie, Southeastern Iran. The study site is located on latitude 31-53- 14 N and 48-40-34 E. and with an elevation of 55 m (handheld Global Positioning System-GPS) receiver (Garmin Ltd., Kansas, USA). The predominant parent material for underlying the area from which most soil formed is the Coastal Plain Sands (Benin formation) of the Miocene-Oligocene geological era. The area has a semiarid tropical climate with two distinct seasons, namely wet and dry seasons. Rainfall distribution is bimodal with peaks during the months of July and September. Temperatures are high and change only slightly during the year. Bulk surface samples (0-15 cm) collected from 5 major wheat soils of Iran were air dried and ground to pass through a 2 mm sieve during 2009/2010 cropping season. 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 h at 25±2°C with 25 mi of 0.01 M $CaCl_2$, containing graded levels of P ranging from 4 to 70 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 and Olsen, 1965). Amount of P sorbed by various soils was calculated as difference between initial and final concentrations of P in equilibrium solution (Patrich and Khahd, 1974). For determining P requirement of individual soils the sorption data were fitted to Freundlich equation given below:

Cs = Concentration in solid phase
C = Concentration in fluid phase
Kf = Freundlich adsorption constant
n = Freundlich exponent

Linear plot of log X versus log c yields a as intercept and n as slope (Roy and de Detta, 1985).

RESULTS

Physico-chemical characteristics of the soils under investigation are shown in Table 1. Soil were generally clay in all the field, indicating similarity in parent material source. Slight variations in soil texture and other properties could be attributed to land use history and differential impact of climatic factors on soils. Soils textures were clay to sandy clay with clay content ranging from 30 to 64%. Soils were aciditic with pH ranging from 6 to 6.8. These were calcareous with lime ranging from 6.41 to 14.3%. Soils were low in organic matter and it ranged from 0.01 to 0.03%. Figure 1a-e show amount of P adsorbed by the 5 soils

Table 1: Physico-chemical characteristics of the soils

RAW	Clay	Silt	Sand	SOC	Ca	Al	CEC	Alsat ($g\ kg^{-1}$)	pH (KCl)
	---------------(g kg^{-1})-------------			-----------------(cmol kg^{-1})-----------------					
1	530	60	610	14	6.6	4.0	19.0	42	6.1
2	640	200	160	25	6.8	3.5	14.0	45	6.0
3	350	420	230	30	7.5	4.4	18.0	56	6.8
4	300	90	350	12	4.3	5.3	20.5	32	6.5
5	300	160	560	23	8.2	3.6	15.5	43	6.0

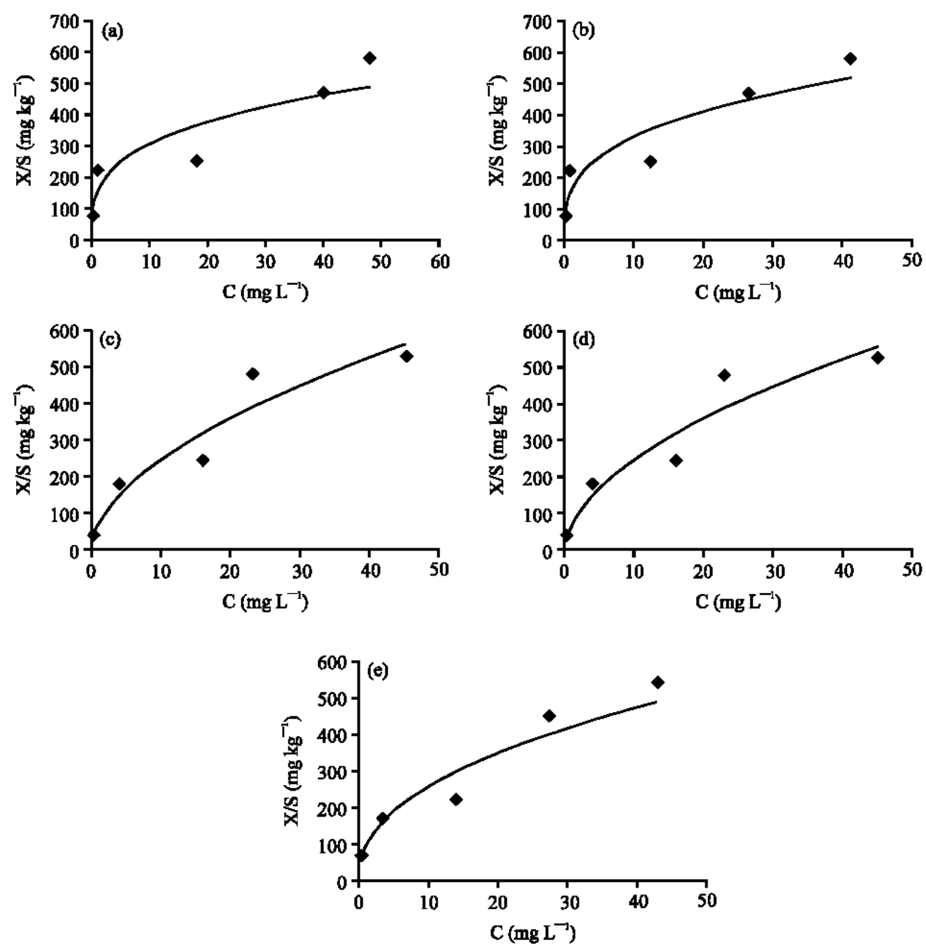

Fig. 1: (a-e) Freundlich adsorption isotherms for 5 soils

Table 2: Values of Freundlich, adsorption parameters

Freundlich equation			
Soil ID	r-s	k	1/n
1	83**	92.1	0.44
2	87**	156	0.32
3	90**	90	0.43
4	87**	111	0.62
5	85**	82	0.30

**Significant at p = 0.01. *Significant at p = 0.05, NS: Not significant

Table 3: 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

Independent variable	Regression equation	R^2
pH (KCl)	Y = 166 pH-382	0.25**
SOC (g kg^{-1})	Y = -10.3 OC+880	0.44ns
Ca (cmol kg^{-1})	Y = -75.6 Ca+1169	0.59ns
Alsat (g kg^{-1})	Y = -8.4 Alsat+1033	0.38**
Clay (g kg^{-1})	Y = 6.9 Clay+370	0.82*

**Significant at p = 0.01. *Significant at p = 0.05, NS: Not significant

increased with increasing P concentration in equilibrium solution with freundlich adsorption isotherm. soil that significant ID = 2 adsorbed the maximum phosphorus. Higher clay content of that soil seems to be responsible for greater adsorption of P as compared to other soils. Several other investigators have also reported such results (Vig and Dev, 1978; Dhillon and Dhillon, 1984). Gaikawad and Patrik (1969) observed that P adsorption followed the Freundlich equation in wheat soils belonging to different ecological zones. Hence, sorption of P by wheat soils used in the present study was best explained by the Freundlich equation. Various values and intercept values calculated for the Freundlich isotherms are shown in Table 2. The R^2 values ranged from 83 to 90%. It shown that Phosphorus adsorption characteristics truly determine with Freundlich adsorption isotherm.

Eleven soils used in this study were similar in their P sorption characteristics, since they all had high clay content and were highly calcareous. 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 are shown on Table 3. Available phosphorus as estimated by $NaHCO_3$, 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 for plant uptake, but it could not correlate with P estimated by $NaHCO_3$-Olsen`s method.

DISCUSSION

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 63 mg kg^{-1} for 3 and 57.1 mg kg for 1-ID series. Soil clay and Alsat influenced adsorption maxima of P in soils. Similar findings were made by Zhang *et al*. (2005) when Soc was correlated with Smax (r = 0.74) while Borling *et al*. (2001) found significant relationships between oxides of aluminium and Smax. there were negative relationship between P adsorption capacity and SOC. Unlike results of other researchers (Dodor and Oya, 2000; Zhang *et al*., 2005) soil pH had significant ($p<0.01$) relationship with P-adsorption. Exchangeable Ca was significantly and negatively correlated ($p<0.05$) with P-adsorption and this contrasts the results of other researchers (Sims *et al.*, 2002). Table 3 shows that Clay in the soil can be a good feature to predict phosphorus absorption in soil and its ability is more than other indices of soil. The amount of calcium in the soil with regression coefficient equal to 59% can use to predict Amount of phosphorus absorbed in the soil. In all soils, P-adsorption characteristics were influenced by some soil properties, although at varying levels. Soil properties that correlated with P- adsorption were pH, SOC Alsat, exchangeable Ca and clay. Similar relationships were recorded by Burt *et al.* (2002). Studied soils are highly weathered and the presence of organic matter reduce P-sorption capacity (Gillman *et al.*, 1989) due to direct result of competition for sorption sites between phosphate and organic ligands (Hakim, 2002). He also reported that the same competition exists between Al and Ca. it is also possible that organic matter reduces positive charge on variable charge surfaces by lowering pH and this decreases the attraction of P to the soil surface indicating that anthropogenic activities do alter soil properties.

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