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USE OF PHOSPHATE SORPTION ISOTHERMS FOR ASSESSING P NEEDS OF MAIZE (*Zea mays*) IN SOME SOIL TYPES OF KARNATAKA

V.S.DODDAMANI[1] AND T.SESHAGIRI RAO[2]

University of Agricultural Sciences, Dharwad.

ABSTRACT

Study of phosphorus sorption isotherms of vertisol (Hanchinal), alfisol (Gubbi), oxisol (Ankola) and inceptisol (Kudalasangum) to predict the P needs of Deccan - 101 maize (***Zea mays*** L,) revealed that an equilibrium P solution concentration of 0.2 ppm would be optimum to get maximum dry matter yield. Per cent phosphorus content of maize was also maximum in all the soil types at an equilibrium P concentration of 0.2 ppm. Near maximum uptake of P by maize in all soil types except oxisol was observed at an equilibrium concentration of 0.2 ppm.

KEY WORDS : Maize, P uptake, Phosphate sorption isotherms.

The phosphate concentration in the soil solution is vital to plant growth (Fox and Kemprath, 1970). If the phosphate concentration in the soil solution is the critical parameter for plant uptake of P, then one needs to take the phosphorus buffering into account in the determination of P fertilizer rate. The phosphorus solution concentration determines the diffusion gradient. The role of the labile fraction is primarily the renewal of P removed from the soil solution by plant roots. Beckwith (1964) suggested that the phosphate sorption, a technique which takes into consideration of P buffering capacity of soil (or capacity factor) and the P in soil solution (or intensity factor) to predict phosphate needs of soils. Ozanne and Shaw (1968) were successful in applying the P sorption isotherm concept in determining fertilizer rates for maximum plant growth. Work on the usability of assessing P needs on the basis of P sorption isotherm for the soil types of Karnataka is lacking. In this paper, Langmuir's adsorption isotherm was adopted to predict the critical P soil solution concentration required to get maximum yield of maize in vertisol, alfisol, oxisol and inceptisols of Karnataka.

MATERIALS AND METHODS

The bulk surface (0-15 cm) soil samples of vertisol, alfisol, exisol and inceptisol collected from Hanchinal, Gubbi, Ankola and Kudalsangam villages respectively were dried in shade and ground to pass

1. Soil Physicist, Advance Centre for Research on Black Cotton soils, U.A..S., Dharwad.

2. Rtd. Prof and Head, Department of Agri. Chemistry & Soils, Agril College. Dharwad - 580 005.

Table 1. Quantity of padded to the treatments in different soil types.

Adjusted equilibrium solution P concentration	Vertisol	Alfisol	Oxisol	Inceptisols
Control	-	-	-	-
0.1 ppm	42.6	53.7	177.0	44.8
0.2 ppm	49.9	64.4	198.2	51.6
0.3 ppm	67.3	74.7	219.4	58.4
0.6 ppm	59.2	106.2	283.0	79.8
0.8 ppm	93.9	227.2	325.4	92.4

through 2 mm sieve for laboratory analysis and 4 mm sieve for pot culture study. Some of the physical and chemical parameters determined following standard methods (Piper, 1950 and Jackson, 1967) are presented in Table 2.

Table 2. Location, textural class nd some of the physico-chemical properties of the soils

S.No.	particulars	Vertisol	Alfisol	Oxisol	Inceptisol
1	Location	Hanchinal	Gubbi	Ankola	Kudalasangam
2	Taluka	Saundatti	Tumkur	Ankola	Hungund
3	District	Belgaum	Tumkur	Uttar Kannada	Bijapur
4	Parent material	Granite gneiss	Granite	Granite	-
5	Texture	Clay	Sandy clay loam	Sandy clay loam	Sandy clay loam
6	Clay (%)	56.25	32.50	23.25	35.00
7	Silt (%)	15.00	6.58	14.25	14.62
8	Sand (%)	7.40	59.34	59.79	47.56
9	pH(1:2, soil : 0.01 M $CaCl_2$)	7.4	5.9	4.3	7.2
10	Organic Carbon(%)	1.318	0.218	1.564	0.323
11	Free $CaCO_3$(%)	10.00	-	-	2.25
12	Free Al_2O_3(%)	0.007	0.050	0.050	0.004
13	Free Fe_2O_3	0.714	1.719	2.201	1.785
14	CEC me/100 g	68.1	14.35	10.31	53.29
15	Total sesqui-oxide (%)	33.23	20.22	22.22	36.67
16	P Kg/ha	12.40	7.82	3.66	5.00

Sorption isothems : Phosphorus adsorption study was done by equilibrating 3 g soil sample for six days at room temperature with 30ml of 0.01 M $cacl_2$ containing graded amounts of $ca(H_2PO_4)_2$.

Two drops of toluene was added per sample to suppress the activity of microorganisms. The soil and solution in the centrifuge tubes were shaken for 30 minutes twice daily (Fox and Kemprath, 1970). At the end of six days the samples were centrifuged and P in the supernatant solution was determined by the sulfomolybdenum blue colour method (Jackson, 1967). The loss of P from equilibrating solution was used to calculate sorbed P. Sorption studies were replicated thrice.

Table 3. Phosphorus adsorbed at various equilibrating P concentrations and that remained in equilibrated solution, phosphorus adsorption maxima and bonding enf soils

S. No.	Location	3.6 ppm		5.4 ppm		7.2 ppm		9 ppm		13.5 ppm		18 ppm		Adsorption maxima μg/g soil	Bonding energy K = ppm^{-1}
		A	B	A	B	A	B	A	B	A	B	A	B		
1.	Vertisol (Hanchinal)	34.33	0.167	52.17	0.183	67.83	0.417	83.88	0.627	124.58	1.042	161.67	1.833	238.559	1.057
2.	Alfisol (Gubbi)	35.33	0.067	57.96	0.104	70.50	0.150	86.67	0.333	126.67	0.833	168.10	1.190	198.791	3.012
3.	Inceptisol (Kudala-sangam)	34.94	0.106	51.97	0.203	68.18	0.382	84.65	0.535	122.65	1.285	171.65	1.835	205.318	1.455
		15 ppm		20 ppm		25 ppm		30 ppm		40 ppm		50 ppm			
4.	Oxisol (Ankola)	149.02	0.098	198.05	0.195	246.65	0.335	293.85	0.615	389.58	1.042	483.87	1.613	574.020	2.426

A = P adsorbed, μg/g soil

B = P remaining in solution, μg/ml

Table 4. Dry matter yield (g/pot) and per cent phosphorus in maize harvested at 30 and 60 days after sowing

S. No.	Adjusted equilibrium P solution concn.	30 days after sowing							
		Vertisol		Alfisol		Oxisol		Inceptisol	
		Dry matter g/pot	% P in plant	Dry matter g/pot	% P in plant	Dry matter g/pot	% P in plant	Dry matter g/pot	% P in plant
1.	Control	1.11	0.115	1.18	0.097	0.64	0.086	0.63	0.090
2.	0.1 ppm	2.18	0.145	1.42	0.111	1.54	0.248	1.75	0.131
3.	0.2 ppm	2.87	0.149	1.82	0.137	2.41	0.268	1.71	0.143
4.	0.3 ppm	2.38	0.169	2.70	0.173	2.11	0.286	1.75	0.130
5.	0.6 ppm	3.10	0.179	2.14	0.198	2.20	0.294	1.83	0.154
6.	0.8 ppm	3.00	0.195	2.80	0.217	2.22	0.357	1.91	0.163
S.Em	±	0.33	0.0023	0.33	0.0017	0.37	0.0057	0.17	0.0036
C.D	at 5%	1.017	0.0071	1.017	0.0052	NS	0.0176	0.524	0.0111
		60 days after soing							
1.	Control	8.09	0.177	6.48	0.140	2.47	0.087	6.99	0.097
2.	0.1 ppm	10.39	0.200	8.84	0.143	12.63	0.127	10.82	0.133
3.	0.2 ppm	12.44	0.250	10.55	0.147	15.80	0.153	12.05	0.143
4.	0.3 ppm	13.44	0.260	11.05	0.143	16.77	0.193	12.78	0.147
5.	0.6 ppm	14.19	0.253	11.48	0.173	16.51	0.260	13.16	0.153
6.	0.8 ppm	14.42	0.243	11.64	0.170	17.32	0.287	14.03	0.163
S.Em	±	1.14	0.0091	1.00	0.0079	0.73	0.0093	7.04	0.0081
C.D.	at 5%	3.513	0.0280	3.081	0.0243	2.249	0.0286	3.205	0.025

The isotherm data were interpreted in terms of Langmuir's adsorption equation and the adsorption maximum values were made use in the regression equation adopted to calculate P to be added to induce solution P concentration levels.

$$\frac{C}{x/m} = \frac{1}{k} \cdot \frac{1}{b} + \frac{c}{b}$$

Where,

C = Equilibrium P concentration in μg/ml.
x/m = P sorbed per g soil in μg
b = P adsorption maximum
k = Constant relating to P bonding strength.

Pot-culture study : Earthen pots lined with polythene sheet were filled with three kg air dried, 4 mm sieved soil.

Six P levels selected and quantity of P added to each treatments in different soil types, as indicated in Table 1.

Monocalcium phosphate $ca(H_2O_4)_2$ dissolved in water was added to the soil as a P source and incubated for 10 days at 60 per cent of water holding capacity. Recommended dose of N and K was added to all the pots. Experiment was replicated twice, following the recommended package of practices.

The seedlings of Deccan-101 variety of maize (*Zea mays* L.) were raised in each pot. One seedling from each pot was harvested at 30 days of sowing and the remaining seedling was cut at 60 days of sowing and dry matter weight was recorded. Phosphorus centent of maize was estimated by standard method (Piper, 1950).

RESULTS AND DISCUSSION

Phosphorus adsorption maximum and bonding strength of different soil types shown in Table 3 indicated that oxisol had the highest P adsorption maxima (574.02 μg/g) followed by vertisol (238.56 μg/g). The lowest P adsorption maxima (198.79 μg/g) was observed in case of alfisol. On the contrary, bonding energy value (3.01) of alfisol was highest followed by oxisol (2.42). The highest P adsorption maxima of oxisol and highest bonding energy of alfisol may be attributed to the enormous specific surface of the highly reactive hydrated Fe and Al oxides and highly weathered material which serve as adsorption sites. The next higher P adosorption maxima of vertisol may be due to high clay content (Table 2). The lower P adsorption maxima of inceptisol as compared to vertisol may be due to the least weathering of this soil. The above findings are in conformity with those reported by Woodruff and Kemprath (1965) and Rajan (1973).

Dry matter accumulation of maize harvested at 30 days after sowing (Table 4) revealed that there was no significant difference in dry matter yield of maize under control and soil solution P concentration of 0.1 ppm in all the soils except oxisols. Futher increase in the equilibrium solution P concentration from 0.1 to 0.8 did not increase the dry matter production significantly. In case of oxisols, the dry matter yield at 30 days after sowing with 0.1 ppm soil solution P concentration was significantly higher than that with no P application, indicating low availability of P in oxisols and response of crop to P application even at lower levels. However, the maximum dry matter yield at 30 days after sowing was noticed, when the equilibrium solution P was adjusted to 0.2 ppm, suggesting that the optimum dose required to be applied should be such that the solution P concentration of 0.2 ppm is attained in the soil.

A plot of dry matter yield of maize at 60 days versus equilibrium solution P concentration indicated a linear relationship between the dry matter yield and soil solution concentration of P. In all the soils, dry matter yield obtained at an equilibrium concentration of 0.2 ppm P was significantly higher than the control and was on par with that obtained at higher equilibrium solution P concentration from 0.3 to 0.8 ppm suggesting that an equilibrium solution P concentration of 0.2 ppm is optimum to obtain higher yields in most of the soils. The amount of P to be added to each type of soil to attain equilibrium solution P concentration of 0.2 ppm corresponds to 124.7, 160.5,495.5 and 129.0 kg/ha for vertisol, alfisol, oxisol and inceptisols, respectively. The above results are in conformity with those reported by Fox and Kemprath (1970) and Mockwunye (1977) who predicted P requirement of millet and corn from the P sorption isotherms and suggested that 0.2 to 0.3 ppm P equilibrium solution concentration was optimum for giving maximum yields of crops.

The available P status estimated by empirical method (Table 2) was rated as low in all soil types except vertisol. On the basis of these soil test results, the recommendation of P to maize crop worked out to 38.6 kg/ha for alfisol, oxisol and inceptisol and 37.0 kg/ha for vertisol. Such recommendation is 2.5 to 5 times less than the predicted value of P at 0.1 ppm equilibrium P concentration at which the dry matter yield of maize in many soils was significantly low as compared to 0.2 ppm P concentration. Futher, the quantity of P to be added to attain 0.2 ppm equilibrium concentration also varied depending on the sorption capacity of soils. It may therefore be concluded that the fertilizer recommendations to crops based on soil test values failed to predict the P requirement of maize crop in different soil types.

The data on per cent P content of maize at 60 days indicated that the tissue concentration of P in maize was highest in all the soil types, at an equilibrium P solution concentration of 0.2 ppm. Similarly the uptake of P by maize was also highest at near equilibrium solution P concentration of 0.2 ppm in all soil types except oxisol. These results confirm the earlier prediction of P requirement of maize crop by adjusting the soil P solution concentration of 0.2 ppm. Jones and Bensen (1975) predicted the P requirement of crops based on equilibrium P concentration at which near maximum yield was obtained.

From the foregoing discussion, it may be suggested that application of P from external sources to bring the equilibrium solution P concentration to 0.2 ppm in different soil types of Karnataka is optimum for getting higher yields of maize. The discussion also leads to the conclusion that P sorption isotherms can give measurement of fertilizer P requirement of crops than the empirical methods.

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