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Forms of soil phosphorus in Terai Zone of West Bengal

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Abstract

Sixty surface soil samples were collected from different parts of Terai agroclimatic region of West Bengal to estimate the various forms of soil P and to evaluate their role in assessing P availability. Ca-P was the dominant inorganic P fraction (35.3%), followed by Fe-P (24.7%), reductant soluble P (24%) Al-P (13.9%) and occluded P (2.2%). Inorganic P (53%) and organic P (47%) were present more or less in equal proportion to total P. Apparently, Olsen-P was found to be a better availability index as it showed higher significant relationship with different inorganic P fractions than Bray P_1, but the latter had a higher correlation coefficient with P uptake by wheat.

Additional key words : P fractions, Terai region, P availability

Introduction

Phosphorus in soil is present in organic and inorganic forms. Only 10 to 30 per cent of the freshly applied phosphate is utilised by crop plants and rest goes into the formation of different P compounds of varying solubility which later serve as potential sources of P for plants (Kanwar 1976). A knowledge of different forms of P and their relationship, availability and other soil properties, viz. pH, organic carbon, calcium carbonate and texture is very useful in assessing P nutrition of plants (Gupta and Lattoo 1999). Keeping in view the scanty information in this respect on soils of Terai agroclimatic region of West Bengal, the present investigation was undertaken.

Materials and methods

Sixty surface (0-15 cm) soil samples were collected from different parts of Terai zone of West Bengal. Soils of this agro-climatic region belong to the orders Inceptisol and Entisol (Status Report 1993). Soils are developed primarily from the deposition brought down by the various rivers originating from the Himalayan hills.

The processed soil samples (<2mm) were analysed for various physical-chemical characteristics, total P by standard methods and inorganic P fractions by the modified method of Chang and Jackson and after Peterson and Corey (Hesse 1998). Organic P was determined as the difference between total P and total inorganic P.

A greenhouse study was conducted with wheat in Neubauer seedling technique by growing 100 wheat seedlings for a period of 17 days in a petridish (11 cm x 7 cm) containing 100g soil and 50g nutrient free quartz. After harvesting dry matter yield was recorded and P uptake by wheat was estimated in triacid digest ($HClO_4$: H_2SO_4:$HClO_4$:: 10:4:1 v/v) by vanadomolybdophosphoric acid yellow colour method.

Results and discussion

The relevant physical and chemical characteristics of the soils are presented in table 1. The soils are strongly acidic to neutral in reaction and marginally low to high in organic carbon and sandy loam to loam in texture. Olsen-P (0.5M $NaHCO_3$, pH 8.5) and Bray-P_1 (0.03N NH_4F+0.025N HCl) varied from 3 to 117 mg kg^{-1} and 1 to 110 mg kg^{-1} with an average of 26 and 20 mg kg^{-1}, respectively.

Table 1. Selected physical and chemical properties of soils.

Properties	Range	Mean
pH (1:2.5)	3.7–7.13	5.12
EC x 100 (dSm^{-1})	0.33–7.4	1.46
Organic Carbon (gkg^{-1})	4.5–26.2	13.4
Clay (gkg^{-1})	92–254	151
Silt (gkg-1)	189–491	285
CEC [cmol(p+)kg^{-1}]	4.67–28.8	16.30
AEC [cmol(p+)kg^{-1}]	1.68–5.66	3.92
Exchangeable (Ca+Mg) [cmol(p+)kg^{-1}]	0.50–9.80	3.12
Exchangeable Al [cmol(p+)kg^{-1}]	0.17–4.77	1.50
Base saturation (%)	4.1–72.9	24.6
Olsen-P (mg kg^{-1})	3–117	26
Bray-P_1 (mg kg^{-1})	1–110	20

Total P content of the soils ranged from 293 to 1868 mg kg^{-1} with an average of 871 mg kg^{-1} (Table 2). The amount of inorganic P (53%) and organic P (47%) in these soils were more or less in equal proportion to total P.

Table 2. Amount of P forms (mg kg^{-1}) in soils and plant parameters in greenhouse experiment

Soil P forms inorganic P	Range	Mean	% of total	% of total P
Al–P	9–277	64	13.9	7.3
Fe–P	10–668	114	24.7	13.1
Ca–P	Trace–561	163	35.3	18.7
R S–P	5–411	111	24.0	12.7
OC–P	3–35	10	2.2	1.1
Total inorganic P	150–1154	462	-	53
Organic P	16–1574	409	-	47
Total P	293–1868	871	-	-
Dry matter yield (g $100g^{-1}$ soil)	1.55–3.05	2.24	-	-
P-uptake by wheat (mg$100g^{-1}$ soil)	2.46-27.03	8.40	-	-

Relatively higher proportion of organic P in these soils compared to other soils was attributed to the relatively higher organic matter content. Among the different inorganic P fractions Ca-P was the most dominant followed by Fe-P, reductant soluble P (RS-P), Al-P and occluded P (OC-P). The amount of Al-P, Fe-P, Ca-P, RS-P and OC-P varied from 9 to 277, 10 to 688, trace to 561, 5 to 411 and 3 to 35 mg kg^{-1} and on an average, constituted 7.3, 13.1, 18.7, 12.7 and 1.1 per cent of total P. Ca-P (35.3%), Fe-P (24.7%) and RS-P (24.0) collectively contributed about 84 per cent of total mineral P. Dominance of Ca-P over other inorganic P forms further supported that the soils were of recent alluvium of north eastern rivers. Dry matter yield and P-uptake by wheat in Neubauer seedling method ranged from 1.55 to 3.05 g 100 g^{-1} soil and 2.46 to 27.03 mg $100g^{-1}$ soil, respectively.

Soil pH had a significant negative relationship with Al-P (r=-0.501**) and RS-P (r=-0.573**) and it was positive with Ca-P (r=0.620**) (Table 3). Availability of P both from Ca-P and Al-P is a pH controlled process. It is worth mentioning that Al-system is more stable at low pH where Ca-system is unstable. Conversely, the Ca-system is more stable under high pH where Al-system is unstable. Exchangeable Ca plus Mg had significant positive correlation with Ca-P (r=0.766**) as well as with total inorganic P (r=0.446**) but negative correlation with Al-P (r=-0.384**), RS-P (r=-0483**) and total P (r=-0.464**).

Table 3. Correlation coefficients (r) between P fractions and soil properties

P forms Properties	Al-P	Fe-P	Ca-P	RS-P	OC-P	Total inorg. P	Org. P	Total P	Total inorg. P + Total P
Clay	−0.217	0.125	0.453	−0.312	−0.101	0.148	−0.227	−0.144	0.270
Silt	−0.301	−0.076	0.218	−0.292	−0.027	-0.115	0.143	0.057	−0.208
CEC	0.361	−0.132	−0.284	0.489	0.209	0.066	0.472	0.426	−0.321
AEC	0.443	0.186	−0.375	0.527	0.099	0.207	0.280	0.372	−0.135
pH	−0.501	−0.133	0.620	−0.573	−0.113	−0.064	−0.093	-0.080	0.096
Org. C	−0.040	−0.103	−0.412	−0.342	0.040	−0.131	0.466	0.337	−0.428
Ex (Ca +Mg)	−0.384	−0.006	0.766	−0.483	−0.086	0.446	−0.167	−0.464	0.246
Ex. Al	0.0673	−0.039	−0.559	0.664	0.340	0.062	0.137	0.149	−0.131
E.C.	0.130	0.165	0.163	0.091	0.177	0.229	-0.166	-0.072	0.249

L.S.C. at 5% and 1% levels for 58 d.f. are 0.250 and 0.325 respectively.

Table 4. Stepwise regression equations of total P and available P with soil forms

Equations	R^2	ΔR^2	Eq. No.
Total P=498+0.91 Org. P	0.646	-	(1)
=323+0.95 Org. P+1.42 Fe–P	0.847	0.201	(2)
=252+0.91 Org. P+1.38 Fe–P+0.82 RS–P	0.886	0.039	(3)
=11+0.99 Org. P+1.22 Fe–P+1.42 RS–P+0.94 Ca–P	0.988	0.102	(4)
=6.7+1.00 Org. P+1.0 Fe–P+1.0 RS–P+1.0 Ca–P+1.04 Al–P	0.999	0.011	(5)
=0.5+1.03 Org.P+1.0 Fe–P+1.0RS–P+1.0 Ca–P+1.0 Al–P+1.03 OC–P	1.0	0.0001	(6)
Olsen P=−4.59+0.266 Fe–P	0.886	–	(7)
=−7.43+0.25 Fe–P+0.07 Al–P	0.899	0.013	(8)
=−12.0+0.24 Fe–P+0.10 Al–P+0.03 Ca–P	0.906	0.007	(9)
Bray P_1=2.15+0.16 Fe–P	0.611	–	(10)
=−4.99+0.15 Fe–P+0.07 RS–P	0.675	0.064	(11)

Likewise exchangeable Al had a positive relationship with Al-P (r=0.673**), RS-P (r=0.664**) and OC-P (r=0.340**) but negative with Ca-P (r=-0.559**). Ca-P and RS-P content in these soils decreased with increase in organic carbon content. This was possibly due to complexation of Ca and Fe by organic anions produced through mineralisation of organic residues (Vig *et al.* 2000). Both the exchange capacities of the soils *i.e.* CEC and AEC had positive relationship with Al-P (r=0.36** and 0.443**), RS-P (r=0.489** and 0.527**), organic P (r=0.472** and 0.280*) and total P (r=0.426** and 0.372**) while negative correlation existed with Ca-P (r=-0.284* and -0.375**). Proportion of inorganic P to total P increased with increase in clay content (r=0.270*) and decreased with increase in CEC (r=-0.321*) and organic carbon (r=-0.428**).

Stepwise regression analysis (Table 4) revealed that organic P alone could explain 64.5 per cent variability in total P and partial contribution of different inorganic P forms were : 20.14, 3.93, 10.15, 1.10 and 0.01% by Fe-P, RS-P, Ca-P, Al-P and OC-P respectively. Generally Al-P and Fe-P are the main sources of available P in acid soils (Mongia and Bandopadhyay 1996). Olsen-P, Fe-P, Al-P and Ca-P collectively contributed 90.6 per cent variation and Bray-P_1, Fe-P accounted for 61.1% variation out of total variation of 67.5% due to Fe-P and RS-P conjointly. Thus, the regression equations showed that Fe-P was the dominant inorganic form of P which contributed maximum to available P extracted by $Bray_1$ and Olsen methods. Thus, the result was in conformity with Sharma *et al.* (1995). The inclusion of other fractions improved the availability indices only marginally i.e. 6.4 to 12%.

Though the above observation apparently indicated that Olsen-P was a better index for assessing available P status of these soils, Bray-P_1 showed higher correlation (r=0.879**) with P uptake by wheat than Olsen-P (r=0.739**). Thus, Bray-P_1 was proved to be the most suitable index for successful assessment of P availability and crop response to the added P in such soils.

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