

Suitability of Soil Test Phosphorus for Phosphorus Fertilization of Terai Soil of West Bengal

S. C. PAUL*, S. RAY AND A. K. GHOSH¹

*Department of Soil Science & Agricultural Chemistry, Uttar Banga Krishi Viswavidyalaya
 Pundibari 736165, India*

¹*Department of Soil Science & Agricultural Chemistry, Institute of
 Agricultural Sciences, Banaras Hindu University
 Varanasi 221005, India*

E-mail : sepaul64@rediffmail.com

**Correspondence*

Abstract

Acid soils generally have low reserve of nutrients and high P adsorption capacity, which may lead to serious fertility problems. Hence soils from diverse land use representing terai region of West Bengal were collected to find out a suitable soil test for P which is necessary to make sound fertilizer recommendation. All soils were moderately to strongly acidic, low in cation exchange capacity, high in organic matter and rich in sesquioxides. Four extractants namely Bray I, Mehlich I, Mehlich III and Olsen, were tested for their suitability of use in terai soils of West Bengal. P extracted by the extractants followed the order Bray I > Mehlich I > Mehlich III > Olsen. P extracted by Bray I extractant was positively correlated to Olsen ($r = 0.94^{**}$) and Mehlich-III ($r = 0.98^{**}$) extractants. Total P content was positively correlated to Bray-I extractable P ($r = 0.83^{**}$), Olsen P ($r = 0.84^{**}$), Mehlich-III P ($r = 0.83^{**}$) but not to Mehlich I P. Dry matter yield by Neubauer seedling technique was correlated to Bray I ($r = 0.628^*$) Olsen ($r = 0.588^*$) and Mehlich III ($r = 0.66^*$) extractants and to total P content of the soils ($r = 0.716^*$). Bray I and Mehlich III were found to be the best extractants followed by Olsen's reagent for estimating P fertility of organic matter rich, acidic terai soil of West Bengal.

Key words : Soil test P, Extractants, Naubauer technique.

Available P refers to the inorganic form occurring in soil solution almost exclusively as orthophosphates ion viz. H_2PO_4^- , HPO_4^{2-} and PO_4^{3-} , the relative abundance of which depends on soil pH. Plants absorb P from the soil solution, which is governed by the heterogeneous equilibria between P adsorbed in solid phase and soil solution. Precipitation and adsorption of P is mainly governed by three elements, Fe, Al and Ca, the first two being the dominant players in acid soils and Ca, in slightly acid to alkaline soils. Only a small fraction of the total P in soil is available to the plant, which depends on soil properties and is of direct relevance in assessing the P fertility level. The success of the phosphorus soil test depends on the choice of the right type of extractant and its correlation to plant uptake. Although a number of soil tests for available P have been tried, each one has its own limitations. Ideally a P soil test would take into account both intensity and quantity fac-

tors. In practice, however, soil tests characterize either the quantity or the intensity factor. Weak extractants evaluate intensity factor whereas strong extractants measure the quantity factor (Kamprath and Watson 1980). Suitability of a proper extractant for base unsaturated soils is important because of the phosphate buffering capacity of the soil. The rate and quantity of P that can be solubilized by a particular extractant depend on the nature of soil inorganic constituent and the chemical nature of the extractant used. Not all extractant being used are suitable for acid soils. Bray-I and Mehlich-I extractants have been recommended for acid soils; the Olsen extractant is being widely used by soil testing laboratories even in acid soil regions of West Bengal; the use of Mehlich-III extractant is slowly picking up as a multi-nutrient extractant. Hence the present study was undertaken to assess the suitability of different extractants for use in acid soils of terai region of West Bengal.

Table 1. Physico-chemical properties of the studied soils.

Soil	pH	Mechanical analysis (%)			Al ₂ O ₃ (%)	Fe ₂ O ₃	CEC Cmol (p+)/ kg	Organic C (%)
		Sand	Silt	Clay				
B ₁	6.09	62.88	26.0	11.12	0.14	0.34	5.10	0.46
B ₂	5.30	74.88	15.0	10.12	0.37	0.40	5.17	1.48
B ₃	5.93	57.88	28.0	14.12	0.10	0.33	4.68	0.67
B ₄	6.72	65.6	22.0	12.4	0.11	0.46	8.19	1.39
Mean	6.01	65.31	22.75	11.94	0.18	0.38	5.78	1.00
Range	5.30-6.72	57.88-74.88	15.0-28.0	10.12-14.12	0.10-0.37	0.33-0.46	4.68-8.19	0.46-1.48
C ₁	5.13	54.84	25.96	19.2	0.33	0.41	4.18	1.38
C ₂	5.75	51.44	27.0	21.56	0.16	0.40	3.30	0.41
C ₃	5.15	51.44	24.0	24.56	0.08	0.26	4.45	0.54
C ₄	4.93	65.88	16.0	18.12	0.15	0.44	3.60	0.84
Mean	5.24	55.9	23.24	20.86	0.18	0.38	3.88	0.79
Range	4.93-5.75	51.44-65.88	16.0-27.0	18.12-24.56	0.08-0.33	0.26-0.44	3.30-4.45	0.41-1.38
F ₁	4.84	78.88	11.0	10.12	0.2	0.17	4.41	1.32
F ₂	5.43	79.88	11.0	9.12	0.11	0.32	3.28	1.30
F ₃	5.15	73.6	15.0	11.4	0.30	0.50	7.65	1.93
F ₄	4.86	62.88	22.0	15.12	0.37	0.50	9.99	2.04
Mean	5.07	73.81	14.75	11.44	0.25	0.37	6.33	1.65
Range	4.84-5.43	62.88-79.88	11.0-22.0	9.12-15.12	0.11-0.37	0.17-0.50	3.28-9.99	1.30-2.04
T ₁	4.96	59.88	20.0	20.12	0.47	0.79	7.45	1.01
T ₂	4.95	67.88	13.0	19.12	0.42	0.48	8.55	1.35
T ₃	4.68	69.6	17.0	13.4	0.27	0.73	7.75	1.40
T ₄	4.57	67.96	20.0	12.04	0.16	0.46	3.60	0.69
Mean	4.79	66.33	17.5	16.17	0.33	0.62	6.84	1.11
Range	4.57-4.96	59.88-69.6	13.0-20.0	12.04-20.12	0.16-0.47	0.46-0.79	3.60-8.55	0.69-1.40

Methods

Composite surface soils (0–15 cm) from fallow (B₁ to B₄), cultivated (C₁ to C₄), forest (F₁ to F₄) and tea garden (T₁ to T₄), representing dominant land use of terai region of West Bengal were collected for the present study. The pH was measured in water using 1:2.5 soil : solution ratio. Texture was estimated by the hydrometer method and organic carbon by wet digestion using chromic acid. The cation exchange capacity (CEC) was measured by the ammonium saturation method using 1N NH₄OAc. Free iron and aluminium oxides were extracted using citrate-bicarbonate-dithionite extractant. Iron in the extract was determined colorimetrically using orthophenanthroline and aluminium by aluminon reagent (Page et al. 1982). Available phosphorus was extracted by four different extractants and phosphorus in the extract was determined colorimetrically using ammonium-molybdate-ascorbic acid method (Page et al. 1982). For the Bray 1 (0.03N NH₄F and 0.025N HCl, pH-2.5) and

Mehlich III (0.2M CH₃COOH + 0.25 M NH₄NO₃ + 0.015M NH₄F + 0.013M HNO₃ + 0.001M EDTA) extractants the soil solution ratio used was 1:10 and Shaking time was 5 minutes. The shaking time was 30 min and the soil solution ratio was 1:20 for Olsen's reagent (0.5M NaHCO₃, pH-8.5). For the Mehlich-I extractant (0.05N HCl and 0.025N H₂SO₄, pH-1.2), the soil solution ratio was 1:4 and shaking time was 5 minutes. Total phosphorus was determined by digesting a suitable amount of soil in a mixture of nitric acid-perchloric acid (9:4). Phosphorus in the digest was estimated by the vanado-molybdate yellow color method (Page et al. 1982). Wheat (variety NW 1014) was grown by Neubauer seedling technique, wherein hundred seeds were sown in Neubauer pots (11 cm × 7 cm) containing 100 g soil from each land use and 50 g nutrient free quartz. The plants were harvested after 17 days, dried at 60 C for 8 hours, digested in diacid mixture (HNO₃ : HClO₄ :: 9:4) and phosphorus in the digest was estimated colorimetrically by vanado-molybdate yellow color method (Piper 1942).

Table 2. Phosphorus extracted by different extractants.

Sample	Bray-1 (mg/kg)	Olsen (mg/kg)	Mehlich-I (mg/kg)	Mehlich-III (mg/kg)
B ₁	3.55	2.7	127.6	4.5
B ₂	244.5	65.75	120.2	60.5
B ₃	4.05	5.43	135.6	4.78
B ₄	12.75	4.07	18.1	11.5
Mean	66.2	19.5	100.3	20.3
Range	3.55-244.5	2.7-65.75	18.1-135.6	4.5-60.5
C ₁	169.5	91.25	68.5	187.0
C ₂	9.75	13.64	40.0	14.85
C ₃	6.3	6.64	86.4	9.61
C ₄	236.0	71.0	76.9	238.5
Mean	105.4	45.6	67.9	112.5
Range	6.3-236.0	6.64-91.25	40.0-86.4	9.61-238.5
F ₁	72.38	26.5	34.0	66.75
F ₂	3.9	7.14	39.1	3.78
F ₃	92.0	46.0	40.0	52.5
F ₄	12.37	8.21	5.5	7.85
Mean	45.2	21.9	29.6	32.7
Range	3.9-92.0	7.14-46.0	5.5-40.0	3.78-66.75
T ₁	31.75	19.7	21.9	36.62
T ₂	70.0	38.75	46.4	54.0
T ₃	96.12	41.75	39.1	66.25
T ₄	8.62	4.43	4.4	6.25
Mean	51.6	26.1	27.9	40.7
Range	8.62-96.12	4.43-41.75	4.4-46.4	6.25-66.25
Overall mean	67.09	28.31	56.48	51.58
Overall range	3.55-244.5	2.7-91.25	4.4-135.6	3.78-238.5

Results and Discussion

Soil Properties

The important soil properties collected from diverse land use system are presented in the Table 1. All the soils, were strongly to moderately acidic, with soil pH ranging from 5.30 to 6.72 (mean 6.01), 4.93 to 5.75 (mean 5.24), 4.84 to 5.43 (mean 5.07) and 4.57 to 4.96 (mean 4.79) in barren, cultivated, forest and tea soil respectively. Due to high rainfall, leaching of bases may have resulted in low soil pH. Contractor and Badnur (1996) have reported low soil pH under forest plantation. Lowest soil pH was found in tea soil, which is maintained at acidic range favorably for tea cultivation. The soils varied in texture ranging from loamy sand to sandy clay loam. Clay contents varied from 10.12 to 14.12 (mean 11.94), 18.12 to 24.56 (mean 20.86), 9.12 to 15.12 (mean 11.44) and 12.04 to 20.12 (mean 16.17) percent in barren, cultivated, forest and tea soil respectively.

The CEC ranged from 4.68 to 8.19 (mean 5.78), 3.3 to 4.45 (mean 3.88), 3.28 to 9.99 (mean 6.33) and 3.6 to 8.55 (mean 6.84) me/100g soil in barren, cultivated, forest and tea soil respectively (Table 1). Significant positive correlation of cation exchange capacity with organic matter ($r = 0.66^{**}$), Fe-oxides ($r = 0.57^*$) and Al-oxides ($r = 0.58^*$) was observed. Organic carbon content varied from 0.46 to 1.39 (mean 1.00), 0.41 to 1.38 (mean 0.79), 1.30 to 2.04 (mean 1.65) and 0.69 to 1.40 (mean 1.11) percent in barren, cultivated, forest and tea soils, respectively. Highest organic carbon content was observed in forest soil resulting from continuous recycling of forest litter and lowest in cultivated soil because of continued tillage operations. The free Al₂O₃ ranged between 0.10 to 0.37 (mean 0.18) for barren soils, 0.08 to 0.33 (mean 0.18) for cultivated soils, 0.11 to 0.37 (mean 0.25) for forest soils and 0.16 to 0.47 (mean 0.33) percent for tea soils. Free Fe₂O₃ varied from 0.33 to 0.46 (mean 0.38) for barren soils, 0.26 to 0.44 (mean 0.38) for cultivated soils, 0.17 to 0.50 (mean 0.37) for forest soils and 0.46 to 0.79 (mean 0.62) percent for tea soils.

Phosphorus Extracted by Extractants

Four extractants were used to estimate labile P from soils of four land uses and the Neubauer Seedling technique was used to find the suitability of these extractants. Highest amount of P was extracted by Bray-1 (range 3.55 to 244.5; mean 67.09 mg/kg) followed by Mehlich-I (range 4.4 to 135.6; mean 56.48 mg/kg), Mehlich-III (range 3.78 to 238.5; mean 51.58 mg/kg) and Olsen (range 2.7 to 91.25; mean 28.31 mg/kg) extractant (Table 2). The high solubility in Bray-1 may be due to its acidity and complexation of Al⁺³ and Fe⁺³ ions with F⁻ ion and consequent release of P adsorbed on to these soil constituents. A similar mechanism of action is also present in Mehlich-III but the strength of NH₄F used is half than that of Bray-1 and hence low amount of P was extracted by Mehlich-III. Ravindra and Ananthanarayana (1999) also reported higher extractability of P by Bray reagent in acid soils of Karnataka as compared to other reagents. Mehlich-I is a diacid extractant with low pH and has H₂SO₄ as a constituent. Sulfate is a good competitor to phosphate for adsorption sites and hence the relative extracting power of these extractant is high. The Olsen extractant was originally developed for neutral

Table 3. Dry matter yield and P uptake by wheat in Neubauer technique.

Sample	Dry matter yield (g)	Phosphorus	
		Concentration in plant (mg/g)	Uptake (mg)
B ₁	3.14	2.32	7.29
B ₂	3.06	2.47	7.56
B ₃	3.12	2.02	6.25
B ₄	3.08	4.00	12.30
Mean	3.10	2.70	8.35
Range	3.06-3.14	2.02-4.00	6.25-12.30
C ₁	3.28	2.42	7.93
C ₂	3.05	1.48	4.51
C ₃	3.21	1.12	3.60
C ₄	3.33	3.26	10.86
Mean	3.21	2.07	6.72
Range	3.05-3.33	1.12-3.26	3.60-10.86
F ₁	2.98	2.32	6.91
F ₂	3.08	2.22	6.83
F ₃	3.16	1.97	6.23
F ₄	3.30	2.57	8.47
Mean	3.13	2.27	7.11
Range	2.98-3.30	1.97-2.57	6.23-8.47
T ₁	3.26	2.76	9.00
T ₂	3.21	1.78	5.70
T ₃	3.19	2.86	9.14
T ₄	2.94	2.32	6.82
Mean	3.15	2.43	7.66
Range	2.94-3.26	1.78-2.86	5.70-9.14

to alkaline calcareous soil and it is buffered at an alkaline pH; the bicarbonate ion can replace some adsorbed phosphate and solubilization of organic matter takes place at alkaline pH. However it has successfully been used as a suitable extractant in acid soils of Himachal Pradesh (Sharma et al. 1985). P extracted by Bray I extractant was positively correlated to Olsen ($r = 0.94^{**}$) and Mehlich-III ($r = 0.98^{**}$) extractants, signifying that Bray-I and Mehlich-III extractant closely resembles those soil constituents from which Olsen reagent also extract P. In fact much of sesquioxides in the soils are complexed to organic matter ($r = 0.56^*$); solubilization of these complexes by Olsen reagent at high pH might have resulted in release of P; Wolf and Baker (1985) also reported similar findings.

The total P content varied from 0.039 to 0.117 (mean 0.064), 0.034 to 0.112 (mean 0.075), 0.019 to 0.063 (mean 0.043) and 0.024 to 0.092 (mean 0.065) percent, under barren, cultivated, forest and tea soils respec-

tively. Total P was positively correlated to free Al_2O_3 ($r = 0.52^*$) and free Fe_2O_3 ($r = 0.40$) suggesting that due to the acid character of the soil, P exist in various combinations of Fe and Al oxides and hydrous oxides. Similar findings also reported by Ravindra and Ananthanarayana (1999). Total P content was positively correlated to Bray-I extractable P ($r = 0.83^{**}$), Olsen P ($r = 0.84^{**}$), Mehlich-III P ($r = 0.83^{**}$) signifying that these extractants extract a part of the total P.

Dry matter yield did not vary much among the soils (Table 3) because of the short time period of the experiment. Phosphorus uptake by wheat as determined by Neubauer seedling technique was not correlated to P extracted by any of these extractants. However, dry matter yield was correlated to Bray I ($r = 0.628^*$) Olsen ($r = 0.588^*$) and Mehlich III ($r = 0.66^*$) extractants but not to Mehlich I. Dry matter yield was also correlated to the total P content of the soils ($r = 0.716^*$) and free Al_2O_3 ($r = 0.60^*$). Apparently all the three extractants viz. Bray 1, Olsen and Melhich III, which extract a part of total P and bear a relationship to dry matter yield, may be treated as a suitable soil test for P. Whereas both Bray I and Mehlich III are acid extractants and rely on complexation of sesquioxide components of soil for extracting P, they are theoretically the extractants of choice for acid soils. Similar results also reported by Jaggi (1992). Olsen's reagent which bears a close relationship between both Bray I and Mehlich III however depends on solubilization principle for extraction of P and hence less P is extracted by Olsen's reagent. However, it can also be used as a suitable extractant for acid soils high in organic matter.

Conclusion

Bray I and Mehlich III are the most suitable extractants of P for acidic terai soils of West Bengal. Olsen's extractant can also be used for acid soils high in organic matter and there is no reason to discourage soil testing laboratories located in terai region of West Bengal from using Olsen's reagent for testing P status of soils. However if the use of Olsen's reagent is to be discontinued as a P soil test for the acid soil regions, it should preferably be replaced by a multinutrient extractant such as Mehlich III, rather than Bray I.

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