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PHOSPHORUS FRACTIONATION IN ACID SOIL OF LAKKATURA TEA GARDEN, SYLHET, BANGLADESH

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ABSTRACT

Islam MR, Rony M, Afroz H, Islam MS, Hoque MM (2014) Phosphorus fractionation in acid soil of Lakkatura tea garden, Sylhet, Bangladesh. *J. Soil Nature* 7(1), 1-6.

Phosphorus (P) availability is affected in acid soils and hence it is important to monitor the distribution of P in acid soils. A study was undertaken to evaluate the distribution of P and its relationship with other nutrients. The soil samples were collected at 0-15 cm and 15-30 cm depths from 0 year, 20 year, 40 year and 60 year tea cultivated soils. The P fractions determined were total P, total organic P, total inorganic P and available P. The available P in soils was extracted with four different extractants *viz.* Olsen, Bray, Nelson and Morgan extractants. The different P fractions varied in their levels and also decreased in subsurface soils. In general, the P fractions were significantly and positively correlated with organic matter, total N and available S contents of soils and negatively correlated with soil pH. The total P content varied from 80.08 to 96.81 ppm at 0-15 cm depth and from 67.73 to 81.95 ppm at 15-30 cm depth in different soils. Among the soils the highest organic P (59.20 ppm) was found in soils of 40 years of tea cultivation. The inorganic P content of soils varied from 29.62 to 37.61 ppm at 0-15 cm depth and from 28.29 to 34.66 ppm at 15-30 cm depth. The organic and inorganic P constituted on an average 59.90% and 40.10% of total P, respectively. The available P content varied considerably with the variation of soils and extractants used. The highest available P content was observed in 40 year aged tea soil with all the extractants while 0 year round cultivated tea soil showed the lowest value. The P values extracted by different extractants followed the order of Bray-P>Nelson-P>Olsen-P>Morgan-P.

Key words: *phosphorus fractions, acid soils, P extractants*

INTRODUCTION

Phosphorus is one of the major plant nutrient elements and it ranks after nitrogen in protein formation of. It is a component of nucleic acids, so it plays a vital role in plant reproduction. Phosphorus is available in soil in three different forms *viz.* $H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}. Phosphorus deficiency is an important traditional problem of acid soils (De Datta 1981).

The tea plant grows well on acidic soils. These soils are strongly leached with a low pH, high aluminum concentration and marginal availability of nutrients. Low availability of P owing to low native content and high P fixation capacity of the soil is one of the main limiting factors to the productivity of tea plants (Lin *et al.* 1992). Accordingly, P fertilization is usually recommended.

The soil solution is the key to plant nutrition because all phosphorus that is taken up by plants comes from phosphorus dissolved in the soil solution. Because the amount of soluble phosphorus in the soil solution is very low, it must be replenished by as many as 500 times during a growing season to meet the nutritional needs of a typical crop. Although very little phosphorus is available in the soil solution at any time, there is a large amount of phosphorus in most soils. The bulk of the soil phosphorus is either in the soil organic matter or in the soil minerals. A large proportion of the phosphorus in both of these fractions is in very stable, unavailable forms, while a much smaller proportion is in available forms that can dissolve in the soil solution and be taken up by plants. The dynamic and available phosphorus in these fractions, such as phosphorus added in fertilizer or manure, can be quickly fixed into stable, unavailable forms in the soil. This is why, even with optimum management, the efficiency of plant uptake of phosphorus is very low—usually less than 20 percent. Organic phosphorus availability depends on microbial activity to breakdown soil organic matter. Thus, organic phosphorus availability is dependent on soil conditions and weather, which influence microbial activity.

The mineralization of organic phosphorus to inorganic forms is favored by optimum soil pH and nutrient levels, good soil physical properties, and warm moist conditions. The inorganic phosphorus in soil bound with iron and aluminum compounds. Replenishment of the soil solution with phosphate from inorganic forms comes from slow dissolution of these minerals. The solubility of phosphorus containing minerals is directly related to soil pH. The pH range of greatest phosphorus availability is 6.0 to 7.0. At a lower pH, when soil is very acidic, more iron and aluminum are available to form insoluble phosphate compounds and, therefore, less phosphate is available. At very high pH, phosphorus becomes unavailable due to formation of calcium complex in the soil. Low soil organic matter content and its rapid decomposition under high temperature further deteriorate P reserve in soils (Hoque and Jahiruddin, 1994).

Basic study with the distribution of P in different soils of Bangladesh is scarce. So it is well justified to conduct a research study with a view to evaluating the P fractions in soils and their distribution for proper management of P in soils.

MATERIALS AND METHODS

The representative soil samples were collected from four different age group of tea crop grown for 0 year, 20 year, 40 year and 60 year in Lakkatura Tea Garden, Sylhet. The soils belong to the Agro-ecological Zone 20 designating Eastern Surma-Kushyara Floodplain. Twenty four composite soil samples were collected from the sampling sites at two different depths of 0-15 cm and 15-30 cm. Soil samples were carried to the laboratory, dried at room temperature, mixed thoroughly, crushed, sieved with a 10-mesh sieve and preserved in plastic bags for subsequent laboratory analyses. Total P in the soil was extracted by digestion with $HClO_4$ and HNO_3 mixture ($HClO_4 : HNO_3 = 1 : 2$) as outlined by Jackson (1958). For determining organic P, the soil sample was ignited with HCl at 240^{o}C for 1 hour in a Pyrex beaker and then P was extracted from the soil with NH_4Mo-HCl solution (Olsen *et al.* 1954). Inorganic phosphorus was determined by subtracting organic phosphorus from the total phosphorus. Available P was extracted from the soil by four different extractants (Table 1). The phosphorus in the extract was determined turbidimetrically. Particle size analysis of soil was done by hydrometer method (Bouyoucos 1927) and the textural class was determined by plotting of the values for %sand, %silt and %clay on the Marshall's Triangular Coordinate (Marshall 1947) following the USDA system. Organic matter was determined by Walkley and Black method (Walkley and Black, 1934). The soils were also analyzed for pH (1:2.5 soil-water) by glass electrode pH meter method(Michael 1965), total N by Semi-micro Kjeldahl method (Bremner and Mulvaney, 1982), available P by Olsen method (Olsen *et al.* 1954), exchangeable K by Flame Photometer after extraction with 1N NH_4OAc at pH 7.0 (Knudsen *et al.* 1982) and CEC (Chapman 1965). Mean, standard deviation and simple correlation were carried out to validate the results.

Table 1. An outline of the methods used for P extraction from soil

Extractant	Soil-extractant ratio	Shaking time (min.)	Reference
0.5N $NaHCO_3$ (pH 8.5)	1:20	30	Olsen *et al*. (1954)
0.03N NH_4F + 0.025N HCl	1:10	30	Bray and Kurtz (1945)
0.05N HC1 + 0.02N H_2SO_4	1:4	30	Nelson *et al*. (1953)
0.54M NH_4OAc + 0.7M NaOAC	1:100	30	Morgan *et al.* (1988)

RESULTS AND DISCUSSION

General characteristics of soils

The general characteristics of the soils under study have been reported in Table 2. The soils were sandy loam to loamy sand in texture and acidic in reaction ranging pH from 3.87 to 4.61 at 0-15 cm depth, and 3.84-4.57 at 15-30 cm depth. The electrical conductivity (EC) of the soils varied from 17.81 to 22.71 µS cm^{-1} and 16.73 to 20.98 µS cm^{-1} at 0-15 cm and 15-30 cm depth, respectively. The organic matter content of the soils ranged from 1.13 to 1.21% at 0-15 cm depth while 0.82 to 0.88% at 15-30 cm depth. In general the N, K, S and CEC contents of the soils were higher in top soils (0-15 cm depth) and lower in sub soils (15-30 cm depth).

Table 2. General characteristics of soils under study

Age	Depth (cm)	Textural Class (USDA)	pH	EC (µS cm^{-1})	Organic Matter (%)	Total N (%)	Available Sulphur (ppm)	K^+ (me/100g soil)	CEC (me/100g soil)
0 Year	0-15	Sandy Loam	4.61	22.71	1.21	0.071	12.24	0.14	8.90
	15-30	Sandy Loam	4.57	20.98	0.88	0.055	9.15	0.13	8.24
20 Year	0-15	Sandy Loam	4.08	21.06	1.16	0.069	10.8	0.13	9.13
	15-30	Sandy Loam	3.95	18.15	0.86	0.053	8.75	0.12	8.89
40 Year	0-15	Sandy Loam	3.87	17.81	1.13	0.064	10.5	0.13	8.26
	15-30	Sandy Loam	3.84	16.73	0.85	0.049	9.53	0.12	7.76
60 Year	0-15	Loamy Sand	3.90	18.49	1.15	0.061	10.14	0.12	8.64
	15-30	Loamy Sand	3.88	17.06	0.82	0.052	8.46	0.11	7.99

Results are the means of three replicates

P fractions in soils

Total P

Total P content in soils has been depicted in Table 3. Total P content of soils ranged from 80.04 to 96.81 ppm at 0-15 cm depth while at 15-30 cm depth it varied from 67.73 to 81.95 ppm in different tea cultivated soils. The highest total P content of 96.81 ppm was found in 40 year tea cultivated soil and the lowest value of 67.67 ppm was found in 0 year tea cultivated soil. In general, the total P status of the soils studied was above the critical level of 8 ppm according BARC (2005). Total P values were higher in 0-15 cm than 15-30 cm soil depth. This might be due to higher content of organic matter in surface soil than subsoil. Chandra and Tripalli (1973) also found higher total P values in surface soil than subsoil.

Table 3. Total, organic and inorganic P status of different soils

Age	Depth (cm)	Total P (ppm)	Organic P (ppm)	Inorganic P (ppm)
0 Year	0-15	80.08±1.99	50.46±1.73	29.62±0.59
	15-30	67.73±2.02	39.44±2.27	28.29±1.35
20 Year	0-15	91.45±2.55	56.41±1.95	35.04±0.89
	15-30	76.16±1.53	42.66±2.93	33.50±2.94
40 Year	0-15	96.81±4.14	59.20±4.20	37.61±0.82
	15-30	81.95±1.34	47.19±1.09	34.66±0.76
60 Year	0-15	84.42±3.34	52.87±1.86	31.55±1.56
	15-30	70.29±2.31	40.45±2.40	29.84±0.12

Results are the means of three replicates; ±, Standard deviation

Organic P

Organic P content of soils varied from 50.46 to 59.20 ppm at 0-15 cm depth but at 15-30 cm depth the value varied from 39.44 to 47.19 ppm (Table 3). The organic P accounted for 62.29-63.01% and 57.71-58.24% of Total P, respectively (Fig. 1). These results were found to be similar compared to observations made by Deepak and Nirmal (1993) who pointed out that organic P made up 43.7-71.3% of total P in some Indian soils. In general the status of organic P decreased in the lower depth of soils showing a very strong correlation with organic matter content of soils. This might be due to lower organic matter content and higher decomposition rate under tropical climate. These results are in agreement with Agarwal and Singh (1995) who also found a decrease in organic P with increasing soil depth.

Inorganic P

Table 3 shows that the inorganic P content of soils ranged from 29.62 to 37.61 ppm with a mean of 33.46 ppm and 28.29 to 34.66 ppm with a mean of 31.57 ppm at 0-15 cm and 15-30 cm depth, respectively which accounted for 36.99-38.85% and 41.76-42.29% of Total P respectively (Fig. 1). These results support the findings of Chowdhury (1992) who found 40% of Total P as inorganic P.

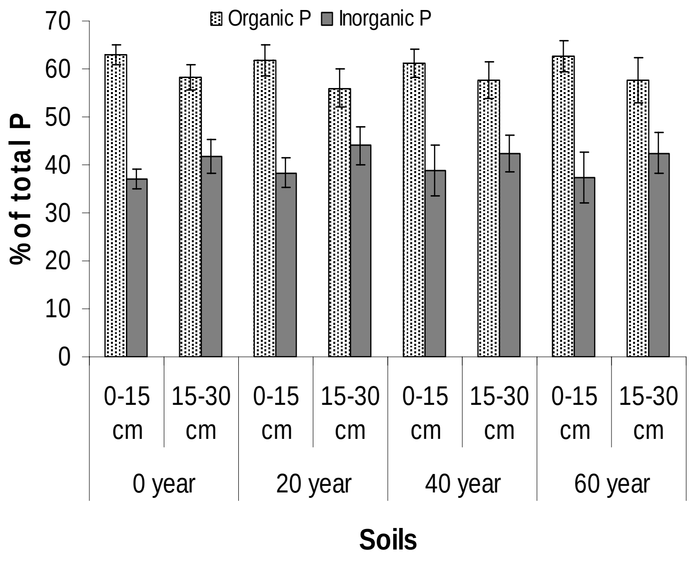

Fig. 1. Organic and inorganic P as a percentage of total P in different soils

Available P extracted with different extractants

The results on available P in soils extracted with different extractants have been reported in Table 4 and described below:

Olsen-P

Results in Table 4 indicate that the Olsen-P ranged from 15.30 ppm to 17.49 ppm at 0-15 cm depth and from 12.53 ppm to 14.50 ppm at 15-30 cm depth in different aged tea soils. The highest content of Olsen-P (17.49 ppm) was found in 40 years tea cultivated soil at 0-15 cm depth and the lowest amount of 12.53 ppm was found in 0 year cultivated soil at 15-30 cm depth. Available P of soil decreased with increasing depth of soils. Similar trend of available P was also observed by Chandra and Tripothi (1973), Fakir (1998) and Ahmed (2002).

Bray-P

Results in Table 4 indicate that the Bray-P ranged from 23.84 ppm to 28.07 ppm at 0-15 cm depth and from 19.57 ppm to 21.78 ppm at 15-30 cm depth in different aged tea soils. The highest content of Bray-P (28.07 ppm) was found in 40 years tea cultivated soil at 0-15 cm depth and the lowest amount of 19.57 ppm was found in 0 year tea cultivated soil at 15-30 cm depth. Available P of soil decreased with increasing depth of soils. Similar trend of available P was also observed by Chandra and Tripothi (1973), Fakir (1998) and Ahmed (2002).

Nelson-P

Results in Table 4 indicate that the Nelson-P ranged from 19.27 ppm to 24.39 ppm at 0-15 cm depth and from 15.73 ppm to 20.03 ppm at 15-30 cm depth in different aged soils. The highest content of Nelson-P (24.39 ppm) was found in 40 years tea cultivated soil at 0-15 cm depth and the lowest amount of 15.73 ppm was found in 0 year tea cultivated soil at 15-30 cm depth. Available P of soil decreased with increasing depth of soils. Similar trend of available P was also observed by Chandra and Tripothi (1973) Fakir (1998) and Ahmed (2002).

Morgan-P

Results in Table 4 indicate that the Morgan-P ranged from 7.84 ppm to 9.01 ppm at 0-15 cm depth and from 6.28 ppm to 7.36 ppm at 15-30 cm depth in different aged tea soils. The highest content of Morgan-P (9.01 ppm) was found in 40 years age cultivated soil at 0-15 cm depth and the lowest amount of 6.28 ppm was found in 0 year age cultivated soil at 15-30 cm depth. The Morgan-P values of all aged soils were low according to BARC (2005).

Table 4. Available phosphorus status of soils as determined by different extractants

Age	Depth (cm)	Available P (ppm) extracted by			
		Olsen-P	Bray-P	Nelson-P	Morgan-P
0 Year	0-15	15.30±1.29	23.84±0.50	19.27±0.33	7.48±0.52
	15-30	12.53±0.95	19.57±0.83	15.73±0.17	6.28±0.39
20 Year	0-15	15.86±0.56	25.92±0.42	22.08±1.26	8.04±0.61
	15-30	13.43±0.34	21.04±0.79	17.60±0.53	7.09±0.41
40 Year	0-15	17.49±0.48	28.07±0.31	24.39±0.83	9.01±0.53
	15-30	14.50±0.89	21.78±1.14	20.03±0.50	7.36±0.41
60 Year	0-15	15.62±0.54	24.94±1.53	21.74±0.42	7.62±0.57
	15-30	12.96±0.29	20.01±0.61	16.78±0.75	6.58±0.32

Results are the means of three replicates; ±, Standard deviation

Result in Table 4 indicates that the available P content of the soils varied considerably with the variation of different soils and extractants used. The highest content of available P was observed in 40 year round cultivated soil estimated with all the extractants. The 0 year round cultivated soil showed the lowest available P determined with all the extractants. None of the soils showed available P content below critical level of 8 ppm except Morgan extractant. Only a few samples showed available P above 8 ppm when determined with Morgan extractants (BARC 2005). The mean values of extractable P differed significantly between the extraction methods except in one case. The mean value of P extracted by Nelson-P was not significantly different from that extracted by Bray-P. The P values extracted by different extractants followed the order of Bray-P>Nelson-P>Olsen-P>Morgan-P.

Relationship between P fractions and some soil properties

Table 5 reports the linear relationship between P fractions and some soil properties. The results indicate that total P was insignificantly correlated with organic matter, total N and soil pH. But organic P was significantly and positively correlated with organic matter (r=0.8377**) and total N (r=0.7191*). There was a significant and negative correlation between inorganic P and soil pH (r=-0.7122*). Olsen-P showed significant and positive correlation with organic matter (r=0.7931*) content of soils but insignificant correlation with total N.

Bray-P showed significant and positive correlation with organic matter (r=0.8378**) and total N (r=0.7254*). Nelson-P showed significant and positive correlation with organic matter (r=0.7075*) content of soils but insignificant correlation with total N. Morgan-P was insignificantly correlated with pH, organic matter, total N.

Table 5. Relationship of Phosphorus fractions with other soil properties

P fractions	Clay	pH	EC	% OM	Total N	Sulphur	K^+	CEC
Total P	0.2339	-0.3752	-0.0341	0.7008	0.5804	0.5763	0.0915	0.2826
Organic P	0.0997	-0.2264	0.1283	0.8377**	0.7191*	0.7111*	0.1779	0.3599
Inorganic P	0.3632	-0.7122*	-0.4416	0.3347	0.1476	0.1562	-0.2559	0.0758
Olsen- P	0.0404	-0.2748	0.0321	0.7931*	0.6553	0.6738	0.1313	0.2573
Bray-P	0.0709	-0.2232	0.1169	0.8378**	0.7254*	0.6812	0.1677	0.3687
Nelson-P	0.0852	-0.4177	-0.0997	0.7075*	0.5409	0.5812	0.0082	0.1939
Morgan-P	0.1762	-0.3538	-0.0554	0.6902	0.5767	0.6010	0.0994	0.2428

*Significant at the 0.05 level of probability

** Significant at the 0.01 level of probability

CONCLUSION

The overall results indicate that the status of various P fractions varied from soil to soil and in some soils the level of available P recorded only a small portion of the total P (0.01%) indicating the existence of P deficiency. The inorganic P content of soils was low in comparison with organic P in different soils. Bray extractant produced the highest available P compared to that extracted with other extractants. Among these four age groups of tea soils, 40 year tea cultivated soil was found to be rich in different P fractions due to management practices over the years.

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