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Dacca University Studies, B. XXVI (2) : 39—51, 1978

VERTICAL DISTRIBUTION OF PHOSPHATE IN SOME SUB-HUMID TROPICAL SOILS OF BANGLADESH

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Abstract

The distribution of organic, inorganic and total phosphates and the reasons of their variation in a number of sub-humid tropical soil profiles has been examined· An appreciable amount of phosphate was found in the surface soils but their amounts decreased with depth. Moderate to well drainage caused a gradual decrease in organic phosphate with depth in most of the soils. Inorganic phosphate showed a heterogenous distribution throughout the profiles and generally decreased with depth in profiles with moderate to well drainage capacity. A sharp decrease in organic phosphate but no definite pattern in inorganic value in deeply and shallowly weathered profiles were observed. A gradual decrease in both the values was generally noticed in most of the alluvial soils. Total phosphate in the soils reflected the same trends as was noticed in organic phosphate distribution. Correlation study suggested that phosphate variation was significantly correlated with organic matter, total nitrogen, pH and clay contents of the soils.

Introduction

Phosphate both in organic and inorganic combinations in soils occupy a unique position in soil fertility and plant nutrition (Bray and Kurtz 1945) and leads to an interest in their determinations. Moreover, organic phosphate is of particular interest in the dynamic biological phases of phosphate cyele (Cosgrove 1967) and that of inorganic phosphate constitutes the major sources of plant phosphate (Enwezor and Moore 1966) and is more mobile in the soil than organic phosphate (Fuller and George 1951). Similar to some other constituents, soil phosphate is subjected to certain distribution throughout the profiles during soil development. Different amounts of phoshate have been reported for soils of temperate zones (Floate 1965 ; Jhon *et al.* 1965). Unfortunately, this problem has received little attention in humid and subhumid tropical regions.

To augment the rather insufficient data on this subject, studies were conducted on the amount of phosphate in some subhumid tropical soils of Bangladesh and an attempt was also made to evaluate the factors affecting the variation of phosphate content in profiles.

Table 1. General characteristics of the soils examined.

Soil series	USDA Soil Texonomy	Soil Tract	Parent material	Internal drainage	Colour	Texture
Kashimpur	Rhodic Paleudults	Madhupur	Tertiary and Plistocene Sediments	Well	Brown	Sandy loam
Bajra	Aeric Fluvaquent	Tista Floodplain	Brahmaputra and Tista Alluvium	Well	Olive grey	Clay
Hiakhu	Plinthic Paleustuls	Hill tract	Formation ditto	Well	Dark brown	Loam
Rangapani	Typic Hapludults	Hill tract	Unconsolidated Tertiary Sediments of Dupitila	Well	Dark brown	Clay loam
Silmondi	Fluvaquentic Haplaquept	Old Brahmaputra	Recent Alluvial deposits	Moderate	Light grey	Silty clay loam
Pirgacha	Typic Dystrochrept	Tista Floodplain	Older Alluvium	Moderate	Pale olive	Sandy clay loam
Domar	Typic Dystrochrept	Tista Floodplain	Brahmaputra and Tista Alluvium	Moderate	Light greyish brown	Sandy loam
Santhia	Aeric Fluvaquentic Haplaquept	Gangetic Floodplain	Older and Oldest Alluvium	Moderate	Greyish brown	Silty clay loam
Sara	Aeric Fluvaquentic Haplaquept	Gangetic Floodplain	Young Alluvium	Moderate	Pale olive	Sandy loam
Belabo	Typic Paleudults	Barind tract	Deeply weathered Madhupur clay	Moderate	Light yellowish brown	Clay loam
Kumira	Typic Haplaquepts	Coastal plain	Tidal Sediments of Chittagong	Moderate	Grey	Silty clay loam
Patanga	Typic Haplaquepts	Coastal plain	Tidal Sediments of Chittagong	Moderate	Olive grey	Clay
Chhiatta	Aeric Haplaquept	Madhupur	Tertiary and Plistocene Sediments	Poor	Light grey	Sandy clay loam
Kalma	Aeric Haplaquept	Madhupur	Tertiary and Plistocene Sediments	Poor	Grey	Clay loam
Bharella	Aeric Fluvaquentic Haplaquept	Comilla basin	Sub-recent Pidmont deposits	Poor	Grey	Clay loam
Gangachara	Aeric Fluvaquentic Haplaquept	Tista Floodplain	Older Alluvium	Poor	Light grey	Clay
Ishurdi	Aeric Fluvaquentic Haplaquept	Gangetic Floodplain	Older and Oldest Alluvium	Poor	Pale olive	Clay loam
Lauta	Aeric Paleaquults	Barind tract	Shallowly weathered Madhupur clay	Poor	Light grey	Clay
Amnura	Aeric Paleaquults	Barind tract	Deeply weathered Madhupur clay	Poor	Light grey	Clay
Olipur	Typic Fluvaquent	Comilla basin	Sub-recent Pidmont deposits	Very Poor	Yellowish brown	Clay loam

Materials and Methods

Soils: Twenty soil samples were collected randomly from Dacca, Comilla, Rangpur, Pabna, Bogra, Chittagong and Chittagong Hill Tracts representing twenty soil series and eight important soil tracts of Bangladesh. The soils were identified on the basis of parent material, internal drainage, sub-soil texture and colour (Table 1). The physico-chemical properties determined are presented in Table 2.

Table 2. Physical and Chemical Properties of Soils (Air Dry Basis).

Soil Series	Depth in cm	pH	Organic matter %	Total nitrogen %	Mechanical Analysis		
					Sand %	Silt %	Clay %
Kashimpur	0—7	6.2	3.18	0.08	58	22	20
	—22	5.4	0.55	0.08	38	25	37
	—50	5.5	0.40	0.07	32	17	51
	—75	5.0	0.13	0.04	28	17	55
	—105	4.9	0.03	0.02	28	15	57
Bajra	0—10	6.6	1.14	0.04	30	27	43
	—37	6.6	1.08	0.02	36	28	36
	—55	6.6	0.72	0.30	23	49	28
	—80	6.9	0.40	0.01	55	20	25
	—112	6.9	0.30	0.01	70	10	20
Hiakhu	0—9	4.7	1.85	0.12	45	25	30
	—27	5.0	1.48	0.08	43	30	27
	—40	4.8	0.66	0.04	45	22	33
	—75	5.0	0.78	0.02	48	27	25
	—95	5.0	0.63	0.01	61	20	19
Rangapani	0—15	5.8	2.08	0.12	44	32	24
	—25	5.9	1.20	0.09	35	33	32
	—47	5.5	0.10	0.07	31	31	38
	—75	6.0	0.75	0.06	33	27	40
	—100	6.5	0.65	0.04	55	20	25
Silmondi	0—12	5.4	1.48	0.11	20	35	45
	—25	5.6	0.72	0.10	20	42	38
	—45	7.0	0.55	0.04	26	44	30
	—75	7.3	0.36	0.01	40	38	22
	—95	7.3	0.24	0.01	24	48	28
Pirgacha	0—12	5.4	1.55	0.06	50	35	15
	—32	5.9	1.21	0.06	45	36	19
	—60	5.9	0.67	0.02	52	36	12
	—137	6.2	0.17	0.01	93	2	5

Continued

Table 2. (Continued)

Soil Series	Depth in cm	pH	Organic matter %	Total nitrogen %	Mechanical Analysis		
					Sand %	Silt %	Clay %
Domar	0—15	4.8	1.47	0.10	75	15	10
	—45	4.9	1.27	0.08	71	17	12
	—62	5.3	0.63	0·04	86	8	6
	—125	5.4	0.20	0.02	95	4	1
Santhia	0—12	6.2	2.23	0.10	18	32	50
	—20	6.4	1.41	0.07	12	33	55
	—50	6.8	1.09	0.06	10	26	64
	—80	7.7	0.62	0.02	28	41	31
	—107	8.1	0.35	0.02	37	35	28
Sara	0—15	8.0	0.72	0.04	76	15	9
	—32	8.0	0.46	0.03	73	17	10
	—50	7.7	0.50	0.03	88	9	3
	—62	8.2	0.70	0.03	55	33	12
Belabo	0—12	5.4	1.67	0.07	40	38	22
	—40	5.1	0.48	0.04	16	42	42
	—55	4.7	0.65	0·03	16	36	48
	—100	4.6	0.53	0.01	15	35	50
	—137	4.9	0.35	0.01	16	35	49
Kumira	0—12	7.3	3.60	0.10	12	36	52
	—20	7.5	1.03	0.08	30	30	40
	—40	8.0	0.62	0.06	23	32	45
	—62	8.0	0.57	0.04	20	34	46
	—130	8.0	0.49	0.02	19	31	50
Patanga	0—15	5.2	1.29	0.09	7	62	31
	—32	6.0	0.76	0.07	4	70	26
	—50	6.5	0.72	0.06	5	70	25
	—77	4.5	0.62	0.05	2	61	37
Chhiatta	0—12	5.2	1.10	0.07	61	30	9
	—30	5.5	0.57	0.04	40	30	30
	—40	5.6	0.31	0.04	28	42	30
	—57	5.4	0.27	0.02	29	42	29
Kalma	0—12	5.2	3.13	1.02	42	29	29
	—22	5.5	0.60	0.02	38	33	29
	—32	5.5	0.87	0.04	37	35	28
	—40	5.3	1.21	0.06	37	34	29

Continued

Table 2. (Continued)

Soil Series	Depth in cm	pH	Organic carbon %	Total nitrogen %	Mechanical Analysis		
					Sand %	Silt %	Clay %
Bharella	0—15	5.6	1.54	0.10	24	35	49
	—32	7.0	1.81	0.14	20	31	49
	—57	7.2	0.67	0.06	9	26	65
	—75	7.4	0.43	0.03	67	17	16
Gangachara	0—17	5.8	1.92	0.09	41	41	18
	—42	7.0	0.86	0.04	41	41	14
	—60	7.0	0.34	0.01	90	6	4
	—90	7.1	0.26	0.01	79	15	6
	—137	7.0	0.60	0.01	42	47	11
Ishurdi	0—10	8.1	1.24	0.11	40	30	30
	—30	8.1	0.88	0.04	29	31	40
	—40	8.0	0.57	0.04	38	34	28
	—70	8.1	0.31	0.02	35	51	14
	—90	8.1	0.31	0.01	46	40	14
Lauta	0—17	5.4	2.40	0.06	18	55	27
	—35	5.5	0.90	0.04	20	44	36
	—52	5.7	0·69	0.03	17	37	46
	—75	5.6	0.36	0.01	17	40	43
Amnura	0—15	5.0	1.15	0.07	30	56	14
	—27	6.0	0.37	0.04	37	50	13
	—47	5.7	0.27	0.02	26	52	22
	—75	5.6	0.22	0.02	26	55	19
Olipur	0—7	5.4	1.13	0.13	24	38	38
	—22	5.0	0.76	0.12	23	36	41
	—50	4.9	0.77	0.11	20	32	48
	—70	5.0	0.74	0.08	27	34	39

Chemical analysis : pH was measured electrochemically by using a Pye Glass electrode, the soil : water ratio being 1 : 2.5. Organic carbon was determined by wet oxidation method (Walkley and Black 1934) and that of organic matter by multiplying per cent organic carbon with the factor 1.72, mechanical analysis by hydrometer method and total nitrogen by Kjeldahl's method. The Mehta *et al.* (1954) was used for determining phosphate contents of the soil samples.

Results and Discussion

A. Organic phosphate contents of the soils :

Investigations showed that there are appreciable amounts of organic phosphate in the surface layers of all the profiles, ranging from 63 (Sara) to 261 ppm (Bajra) with an average of 153 ppm (Fig. 1A-D). The greater concentration of organic phosphate in the upper layers was also reported by other investigators in both temperate and humid tropical soils (Gupta and Singh 1972 ; Bhan and Shanker 1973).

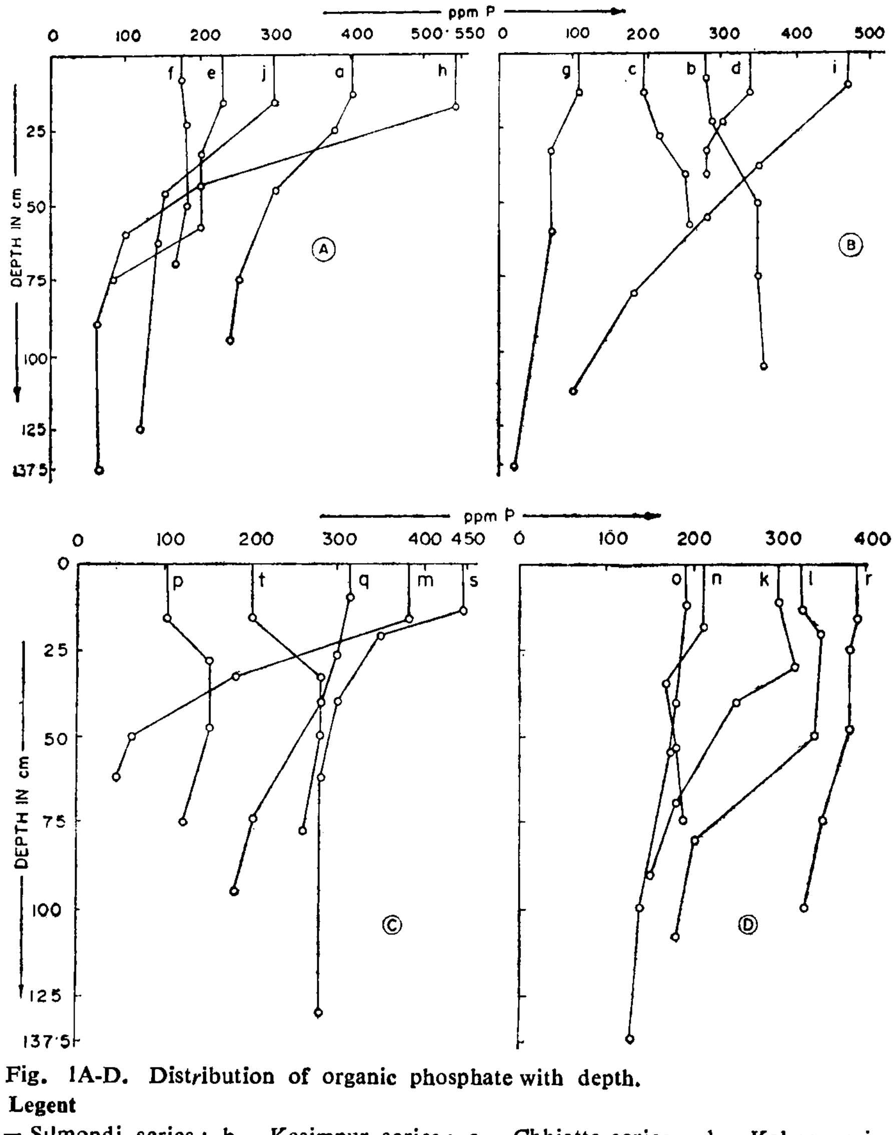


Fig. 1A-D. Distribution of organic phosphate with depth.

Legent

a = Silmondi series ; b = Kasimpur series ; c = Chhiatta series ; d = Kalma series ; e = Bharella series ; f = Olipur series ; g = Pirgacha series ; h = Gangachara serie ; i = Bajra series ; j = Domar series ; k = Ishurdi series ; l = Santhia series ; m = Sara series ; n = Lauta series ; o = Belabo series ; p = Amoura series ; q = Hiakhu series ; r = Rangapani series ; s = Kumira series ; t = Ptanga series ;

The vertical distribution of organic phosphate in the profiles showed four different trends. (1) Non-continuous stepwise decrease, (2) slow sigmoidal change, (3) non-sequential abrupt change, and (4) rapid decrease with depth.

Most of the moderate to well-drained soils caused a non-continuous stepwise, slow sigmoidal change and rapid decrease with depth. While most of the poorly drained soils caused a non-sequential abrupt change with depth. Poor drainage probably impedes the movement of phosphate in solution to the lower horizons during eluviation.

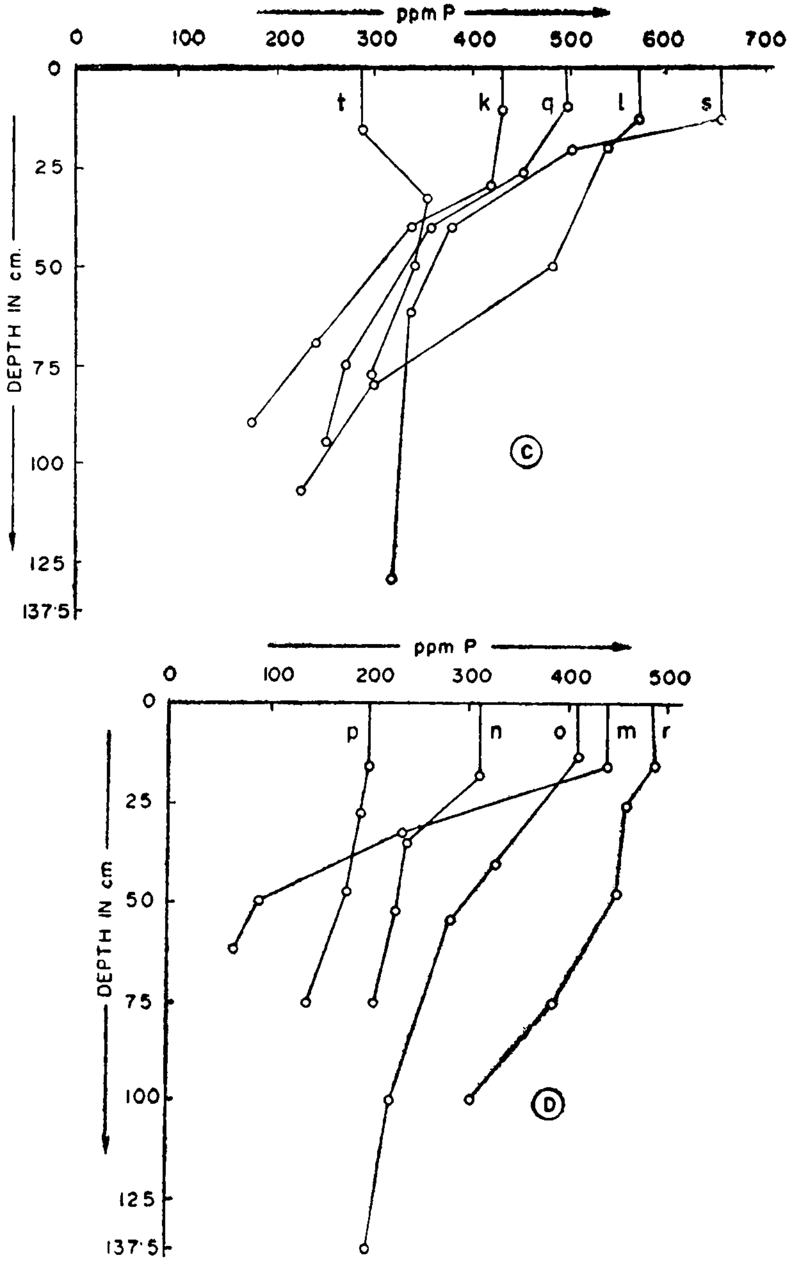
A close association of the distribution of organic phosphate in the profiles was observed with state of weathering (Table 1 and Fig. 1A-D). All the soils of deeply and shallowly weathered Madhupur and Barind tracts showed a sharp decrease and that of recently formed alluvial soils of Floodplains caused a gradual decrease in organic phosphate with increasing depth in most of the profiles.

B. Inorganic phosphate contents of the soils :

The values for inorganic phosphate contents in the surface soils ranged from 102 (Amnura) to 592 ppm (Gangachara) with an average of 298 ppm (Fig. 2A-D). This findings corroborated well with the reports of other temperate as well as humid tropical soils (Bhan and Shanker 1973 ; Uriyo and Kesseba 1973).

The concentrations of inorganic phosphate in the profiles indicated four different trends (Fig. 2A-D). (1) In most cases (13 cases—a, d, e, f, g, h, i, j, m, o, q, r and s lines in Fig. 2A-D), the amount decreased more or less gradually. (2) A slight increase from surface upto the lowest layer was observed in Kashimpur and Chhiatta series (b and c lines in Fig. 2B). (3) One series only, Lauta displayed an initial decrease from surface to the next layer and then a slight increase with depth (n line in Fig. 2D). (4) An initial increase from surface to the sub-surface with a final decrease with depth was found in the remaining four series (k, l, p and t lines in Fig. 2C-D).

Soils with moderate to well-drainage capacity generally showed a gradual decrease in inorganic phoshphate contents with depth except Domar, Bajra, Gangachara and Sara series where a sharp decrease was observed. However, no definite pattern in inorganic phosphate distribution was noticed in deeply and shallowly weathered soils. But in most cases, generally a gradual decrease with depth existed in recently formed alluvial soils. Increase as well as decrease in inorganic phosphate with depth was also reported by Falyush (1969) in tropical soils.



Figs. 3A—D, Distribution of total phosphate with depth. (For legends see Fig.1A—D.)

some parts of Madhupur tract, Barind tract, Comilla basin and northern part of Tista floodplain. The areas which are optimum in total phosphate are Gangetic floodplain and eastern part of Tista floodplain while the areas that are sufficient in this value is the western part of Tista floodplain.

D. Association of phosphate with soil properties :

Similar to other constituents, soil phosphates are subjected to certain distribution throughout the profile during soil formation and occurrence of phosphates in deeper horizon is likely to be the result of, (a) phosphate initially present in soil matterial, (b) movement of phosphates, added as fertilizers, and (c) in *situ* decomposition of plant materials in the soil.

Phosphate distribution and accumulation are influenced by the physical and chemical environments existing in the horizons and is greatly accredited to the soil forming materials. In well-drained cultivated soils, added fertilizer is ploughed under and major portion of the phosphatic fertilizer remains in the plough layer in insoluble forms but a portion moves down with the soil solution. Phosphates that remained in the plough layer in these forms may be reduced to soluble forms and move down in the seasonally water-logged soils. Humified organic matter in the soil solution and as clay-humus complex move downwards. Moreover, the distribution of phosphate in the profiles is also regulated by soil population, penetration of plant roots and their subsequent decomposition.

As revealed from single and multiple correlation study, the phosphates (organic, inorganic and total) are significantly correlated with organic matter, total nitrogen. pH and clay-contents of the soils (Table 3). Increase in

Table 3. Single and multiple correlation co-officients between phosphate and organic matter. total nitrogen, pH and clay contents of the soils.

Correlation between	Correlation co-efficients calculated.
Organic phosphate and organic matter	+0.667 (p=0.001)
Organic phosphate and total nitrogen	+0.741 (p=0.001)
Organic phosphate and pH	+0.225 (p=0.02)
Organic phosphate and clay	+0.190 (p=0.1)
Inorganic phosphate and organic matter	+0.523 (p=0.001)
Inorganic phosphate and total nitrogen	+0.489 (p=0.001)
Inorganic phosphate and pH	−0.226 (p=0.05)
Inorganic phosphate aud clay	+0.562 (p=0.001)
Total phosphate and organic matter	+0.569 (p=0.001)
Total phosphate and total nitrogen	+0.444 (p=0.001)
Total phosphate and pH	−0.146 (p=0.1)
Total phosphate and clay	+0.686 (p=0.001)
Total phosphate and organic phosphate	+0.502 (p=0.001)
Total phosphate and inorganic phosphate	+0.521 (p=0.001)
Organic phosphate and all the factors	+0.860 (p=0.001)
Inorganic phosphate and all the factors	+0.808 (p=0.001)
Total phosphate and all the factors	+0.868 (p=0.001)

inorganic phosphate with clay was also reported by Dormar and Webster (1968) in some temperate soils of Alberta. "Organic phosphate had been shown to exhibit distribution within soil profiles similar to that or organic matter and nitrogen in general" (Pearson and Simonson 1939 ; Jhon *et al.* 1965) and "would be expected to decrease with organic matter with increasing depth" (Pierre 1948 ; Floate 1965). The organic matter contents of the soils decreased with increasing depth (Table 2).

pH from its influence on the solubility products of inorganic phosphate compounds and consequently the weathering of phosphate in the profiles. The occurrence of iron, aluminium or calcium bound phosphate in soil also depends on the pH of the medium.

Soils generally rich in kaolinitic clay adsorbed appreciable amount of phosphate and along with its downward movement, there is possibility of some adsorbed phosphate to be moved downward.

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