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AMOUNTS AND MINERALIZATION OF ORGANIC PHOSPHORUS COMPOUNDS AND DERIVATIVES IN SOME SURFACE SOILS OF BANGLADESH

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ABSTRACT

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Concentrations of a few organic phosphorus compounds and their hydrolysis products have been determined in a number of Bangladesh soils. The amounts of DNA and its derivatives, inositol penta- and hexaphosphates, ranged from 0.16 to 1.30, and 18.5 to 130.0 ppm, respectively. The hydrolysis products of phospholipids such as choline, ethanolamine and glycerophosphate ranged from 0.36 to 3.29, 0.28 to 2.52 and 0.20 to 1.05 ppm, respectively. Multiple correlation suggested that pH, organic matter, organic phosphorus and total phosphorus were collectively related to the amounts of different organic phosphorus fractions in soil samples. Individually, DNA and its derivatives were found to be significantly related to total phosphorus and inositol penta- and hexaphosphates to organic phosphorus. Choline was significantly related to organic matter, organic phosphorus and total phosphorus; ethanolamine to organic matter and total phosphorus; and glycerophosphate to organic phosphorus.

Moisture and lime promoted progressive mineralization of organic phosphorus with time. Potassium dihydrogen phosphate, glucose and ammonium sulphate showed rapid initial and final mineralization. In contrast, the application of compost caused an initial luxury immobilization followed by a marked increase in mineralization with time. Maximum mineralization was observed when ammonium sulphate was added to samples in submerged conditions. The least mineralization occurred when lime was added to samples at 50% of field moisture capacity.

INTRODUCTION

Organic phosphorus compounds identified in soils to date are mostly inositol phosphate and its hydrolysis products (Omotoso and Wild, 1970; Flaig, 1971; Anderson and Malcolm, 1974), phospholipids and their hydrolysis products (Hance and Anderson, 1963; Kowalenko and McKercher, 1971) and nucleic acids and their derivatives (Adams et al., 1954; Fabry, 1960). The chemical nature of the greater part of the soil organic phosphorus is still obscure and likely to be of microbial origin (Cosgrove, 1967). The organic

TABLE I

General characteristics of the soil samples examined

Soil Series	USDA Soil Taxonomy	General soil type	Parent material	Drainage	Texture	Colour
Silmondi	Fluvaquentic Haplaquept	GFS	Recent alluvial deposits	Poor	Silty clay	Light grey
Kashimpur	Rhodic Paleudults	DRBTS	Tertiary and Pleistocene sediments	Well	Loam	Brown
Chhiata	Aeric Haplaquept	GTS	Tertiary and Pleistocene sediments	Poor	Silt	Light grey
Kalma	Aeric Haplaquept	GTS	Tertiary and Pleistocene sediments	Poor	Silty clay loam	Grey
Bharella	Aeric Fluvaquentic Haplaquept	GFS	Sub-recent Piedmont deposit	Poor	Silty clay loam	Grey
Olipur	Typic Fluvaquent	NA	Sub-recent Piedmont deposits	Very poor	Silty clay loam	Yellowish brown
Pirgacha	Typic Dystrochrept	NBFS	Older alluvium	Moderate	Silty loam	Pale olive
Gangachara	Aeric Fluvaquentic Haplaquept	GFS	Older alluvium	Poor	Loam	Light olive
Bajra	Aeric Fluvaquent	NA	Brahmaputra and Tista alluvium	Poor	Silt loam	Olive grey
Domar	Typic Dystrochrept	NBFS	Brahmaputra and Tista alluvium	Moderate	Fine sandy loam	Light greyish brown
Ishurdi	Aeric Fluvaquentic Haplaquept	CBFS	Older and oldest alluvium	Poor	Silty clay	Pale olive
Santhia	Aeric Fluvaquentic Haplaquept	CDGFS	Older and oldest alluvium	Poor	Clay	Greyish brown
Sara	Aeric Fluvaquentic Haplaquept	CBFS	Young alluvium	Poor	Loam	Pale olive
Lauta	Aeric Paleaquults	GTS	Shallowly weathered Madhupur clay	Poor	Silty clay loam	Light grey
Belabo	Typic Paleudults	DRBTS	Deeply weathered Madhupur clay	Moderate	Loam	Light yellowish brown

Amnura	Aeric Paleaquults	GTS	Deeply weathered Madhupur clay	Poor	Silt loam	Light grey
Hiakhu	Plinthic Paleustuls	BHS	Formation ditto	Well	Sandy loam	Dark brown
Rangapani	Typic Hapludults	BHS	Unconsolidated Tertiary sediments of Dupitila	Well	Loamy sand	Dark brown
Kumira	Typic Haplaquepts	GFS	Tidal sediments of Chittagong coastal plane	Poor	Silty clay	Grey
Patanga	Typic Haplaquepts	GFS	Tidal sediments of Chittagong coastal plane (young)	Poor	Silt loam	Olive grey

GFS = grey floodplain soil; DRBTS = deep red brown terrace soil; GTS = grey terrace soil; NA = noncalcareous alluvium; NBFS = noncalcareous brown floodplain soil; CBFS = calcareous brown floodplain soil; CDGFS = calcareous dark grey floodplain soil; BHS = brown hilly soil.

forms of phosphorus are very important in soil fertility because they are, in general, an indirect source of available forms (Bray and Kurtz, 1945); but they contribute very little to phosphorus assimilation by plants unless mineralized (Williams, 1950; Eid et al., 1951). Moreover, the extent of availability of phosphorus through mineralization depends to a greater extent upon the chemical nature of phosphorus present in organic complexes. Islam and Ahmed (1973) estimated the ranges in amounts of a few compounds in some Bangladesh soils without referring to their chemical nature.

Laboratory experiments were therefore performed to estimate the various organic phosphorus compounds present in some soils of Bangladesh and to follow the mineralization of total organic phosphorus under different conditions.

MATERIALS AND METHODS

Materials

Samples of surface soils (0—12 cm) were collected from nine tracts of Bangladesh. A general description of the soil samples along with their classification according to USDA Soil Taxonomy is presented in Table I. Some of their physical and chemical properties are also presented in Table II.

Chemical analyses

pH was measured electro-chemically by using a Pye glass electrode, the soil and water ratio being 1 : 2.5. Organic carbon was determined by Tinsley's wet combustion method as described by Bremner and Jenkinson (1960). The method of Mehta et al. (1954) was used for determining organic and total phosphorus. Analyses were made by methods outlined for inositol phosphate by Omotoso and Wild (1970), phospholipids and their hydrolysis products by Hance and Anderson (1963), DNA and its derivatives by Anderson (1961), and inositol penta- and hexaphosphates by McKercher and Anderson (1968).

Incubation experiments

Experiments were carried out to study the influence of each of moisture, lime, compost, potassium dihydrogen phosphate, glucose and ammonium sulphate on the mineralization of organic phosphorus in soil samples. 500 g of soil samples were placed in 600 ml tubes (15 cm × 7 cm, locally prepared polythene tubes). Different amounts of calcium carbonate were added to bring the pH of the samples to 6.0, 6.5, 7.0 or 8.0. Each was then incubated at 50% field moisture capacity. Compost, potassium dihydrogen phosphate, glucose and ammonium sulphate were each added at the rate of 112.08 kg/ha independently. Each was then again incubated at 25%, 50%, 100% of field moisture capacity and under a submerged condition. Mineralization has also

TABLE II

Some physical and chemical properties of soil samples

Soil Series	pH	Organic matter (%)	Organic phosphorus (ppm)	C/P	Total phosphorus (ppm)
Silmondi	5.40	1.49	158	55	561
Kashimpur	6.20	2.03	253	47	532
Chhiatta	5.15	1.10	155	41	348
Kalma	5.20	1.89	203	54	543
Bharella	5.60	1.54	63	143	293
Olipur	5.40	1.13	114	58	285
Pirgacha	5.40	1.55	124	73	231
Gangachara	5.80	1.92	103	109	694
Bajra	6.60	1.14	261	25	730
Domar	4.75	1.47	215	40	517
Ishurdi	8.05	1.24	129	56	430
Santhia	6.20	2.23	232	56	562
Sara	8.00	0.72	63	67	442
Lauta	5.40	2.40	99	141	312
Belabo	5.40	1.67	216	45	410
Amnura	5.00	1.15	98	68	201
Hiakhu	4.70	1.85	177	61	491
Rangapani	5.75	2.08	98	123	488
Kumira	7.30	3.60	213	98	658
Patanga	5.20	1.29	95	79	297

been studied at different moisture levels without additions of these materials. Every effort was made to keep the moisture content constant during the experiments by the addition of distilled water whenever needed. Each treatment was replicated thrice and arranged in a completely randomized design. The tubes were not covered and incubation was carried out at room temperature (27°C ± 0.5°C). Samples were then analyzed for net changes in inorganic phosphorus levels after 0, 3, 7, 15, 30 and 60 days from the beginning of incubation.

RESULTS AND DISCUSSION

Distribution of organic phosphorus fractions and hydrolysis products of inositol phosphates and phospholipids

Values for inositol phosphates and phospholipids measured in the present investigation were more or less similar to those reported earlier by Islam and Ahmed (1973) and likewise they were related to the soil factors in the same fashion.

Values for DNA and its derivatives, inositol penta- and hexaphosphates, choline, ethanolamine and glycerophosphate are presented in Table III. Con-

TABLE III

Different organic phosphorus fractions and hydrolysis products of inositol phosphate and

Soil Series	Different organic phosphorus fractions						Hydrolysis products	
	inositol phosphates		phospholipids		DNA and it's derivatives		inositol phosphates	
							inositol penta- and hexaphosphates	
	ppm	%**	ppm	%**	ppm	%**	ppm	%**
Silmondi	65.0	41	3.0	1.90	1.30	0.82	40.0	25
Kashimpur	128.5	51	3.0	1.19	0.66	0.26	90.5	36
Chhiatta	64.7	41	1.5	0.97	1.20	0.66	42.0	27
Kalma	75.0	37	3.0	1.48	0.80	0.39	52.0	26
Bharella	30.0	48	3.0	4.76	0.56	0.89	18.5	29
Olipur	72.4	64	1.8	1.58	0.62	0.54	50.6	44
Pirgacha	64.8	52	3.5	2.82	0.75	0.60	35.0	28
Gangachara	84.0	82	4.5	4.37	1.20	1.17	60.0	58
Bajra	100.0	38	4.2	1.61	0.78	0.30	85.0	33
Domar	73.0	34	3.6	1.67	1.10	0.51	45.0	21
Ishurdi	82.2	64	2.0	1.55	0.62	0.48	65.0	50
Santhia	183.1	79	5.5	2.37	0.84	0.36	130.0	56
Sara	45.0	71	1.0	1.59	0.70	1.11	30.5	48
Lauta	35.6	36	3.6	3.64	0.62	0.63	22.5	23
Belabo	90.0	42	4.6	2.13	0.16	0.07	68.5	32
Amnura	46.5	47	2.0	2.04	0.56	0.57	30.5	31
Hiakhu	80.0	45	4.2	2.37	1.10	0.62	63.5	36
Rangapani	58.2	59	4.0	4.08	0.60	0.61	40.5	41
Kumira	160.0	75	7.0	3.29	0.73	0.34	110.0	52
Patanga	44.0	46	3.0	3.16	0.48	0.51	30.4	32
LSD at 1% level	8.84		0.80		0.16		6.64	
Maximum	183.1	82	7.0	4.76	1.30	1.17	130.0	58
Minimum	30.0	34	1.0	0.97	0.16	0.07	18.5	21

*Percentages were calculated on the basis of phospholipids.
**Percentages were calculated on the basis of organic phosphorus.

centrations of DNA and its derivatives, inositol penta- and hexaphosphates ranged from 0.16 to 1.30 ppm and 18.5 to 130.0 ppm, respectively. These constituents comprised about 0.07 to 1.17% and 21 to 58% of organic phosphorus, respectively. Choline, ethanolamine, and glycerophosphate ranged from 0.36 to 3.29 ppm, 0.28 to 2.52 ppm, and 0.20 to 1.05 ppm, respectively. These components constituted about 0.23 to 2.38%, 0.22 to 1.67%, and 0.19 to 0.91% of the organic phosphorus, respectively. Choline, ethanolamine and glycerophosphate accounted for 20 to 50%, 15 to 39%, and 10 to 30% of the total lipid phosphate, respectively.

phospholipids of soil samples

phospholipids								
choline			ethanolamine			glycerophosphate		
ppm	%*	%**	ppm	%*	%**	ppm	%*	%**
1.20	40	0.76	0.90	30	0.57	0.75	25	0.47
1.20	40	0.47	0.69	23	0.27	0.81	27	0.32
0.36	24	0.23	0.51	34	0.33	0.30	20	0.19
1.50	50	0.74	0.45	15	0.22	0.81	27	0.40
1.50	50	2.38	1.05	35	1.67	0.30	10	0.48
0.36	20	0.32	0.54	30	0.47	0.45	25	0.39
1.40	40	1.13	0.70	20	0.56	1.05	30	0.85
2.25	50	2.18	1.26	28	1.22	0.63	14	0.61
1.47	35	0.56	1.05	25	0.40	0.84	20	0.32
1.62	45	0.75	0.54	15	0.25	0.90	25	0.42
0.70	35	0.54	0.66	33	0.51	0.40	20	0.31
2.65	48	1.14	1.76	32	0.76	0.77	14	0.33
0.45	45	0.71	0.28	28	0.44	0.20	20	0.32
1.08	30	1.09	1.26	35	1.27	0.90	25	0.91
1.84	40	0.85	1.61	35	0.75	0.46	10	0.21
0.62	31	0.63	0.70	35	0.71	0.36	18	0.37
1.26	30	0.71	1.47	35	0.83	0.84	20	0.47
1.12	28	1.14	1.56	39	1.59	0.76	19	0.78
3.29	47	1.54	2.52	36	1.18	0.70	10	0.33
1.23	41	1.29	0.81	27	0.85	0.60	20	0.63
0.60			0.41			0.31		
3.29	50	2.38	2.52	39	1.67	1.05	30	0.91
0.36	20	0.23	0.28	15	0.22	0.20	10	0.19

The values obtained in the present study compared well with findings of other investigators. DNA and its derivatives constituted 0.2 to 1.9% (Adams et al., 1954) and 0.5 to 1.0% (Fabry, 1960) of the organic phosphorus in some British soils. Inositol hexaphosphate accounted for 3 to 52% of organic phosphorus in some soils of the United States (Caldwell and Black, 1958). Inositol penta- and hexaphosphates ranged from 13 to 50% of the organic phosphorus in a number of Canadian and Scottish soils (McKercher and Anderson, 1968). Choline and ethanolamine accounted for 0.5—1.9% and 0.39 1.60% of the organic phosphorus, respectively, and about 40 and 30% of the lipid phosphate, respectively, in some Canadian soils (Kowalenko and McKercher, 1971). Glycerophosphate constituted 52—86% of the lipid phosphate in some British soils (Hance and Anderson, 1963).

In order to assess the reasons for differing amounts of these components in soil samples, single and multiple correlations were calculated with pH, organic matter, organic phosphorus and total phosphorus (Table IV). Multiple correlations suggested that all these factors contributed together to differing amounts of these constituents in soil samples. However, individually DNA and its derivatives were significantly related to total phosphorus at the 5% level. Inositol penta- and hexaphosphates were significantly related to organic phosphorus at the 0.1% level and total phosphorus at the 1% level, but the relation was better between inositol penta- and hexaphosphates and organic phosphorus. Choline was significantly related to organic matter at the 1%

TABLE IV

Single and multiple correlation coefficients between different fractions of organic phosphorus and pH, organic matter, organic phosphorus and total phosphorus of the soil samples

	Correlation coefficients calculated
DNA and its derivatives and pH	−0.176(n.s.)
DNA and its derivatives and organic matter	+ 0.041(n.s.)
DNA and its derivatives and organic phosphorus	+ 0.142(n.s.)
DNA and its derivatives and total phosphorus	+ 0.468(p=5)
Inositol penta- and hexaphosphates and pH	+ 0.010(n.s.)
Inositol penta- and hexaphosphates and organic matter	+ 0.331 (n.s.)
Inositol penta- and hexaphosphates and organic phosphorus	+ 0.768(p=0.1)
Inositol penta- and hexaphosphates and total phosphorus	+ 0.647(p=1)
Choline and pH	+ 0.099(n.s.)
Choline and organic matter	+ 0.678(p=1)
Choline and organic phosphorus	+ 0.465(p=5)
Choline and total phosphorus	+ 0.580(p=1)
Ethanolamine and pH	+ 0.104(n.s.)
Ethanolamine and organic matter	+ 0.886(p=0.1)
Ethanolamine and organic phosphorus	+ 0.274(n.s.)
Ethanolamine and total phosphorus	+ 0.395(p=10)
Glycerophosphate and pH	−0.304(n.s.)
Glycerophosphate and organic matter	+ 0.255 (n.s.)
Glycerophosphate and organic phosphorus	+ 0.476(p=5)
Glycerophosphate and total phosphorus	+ 0.336(n.s.)
DNA and its derivatives and all factors	+ 0.668(p=10)
Inositol penta- and hexaphosphates and all factors	+ 0.918(p=0.1)
Choline and all factors	+ 0.874(p=0.1)
Ethanolamine and all factors	+ 0.924(p=0.1)
Glycerophosphate and all factors	+ 0.662(p=10)

level, organic phosphorus at the 5% level and total phosphorus at the 1% level. The highest correlation of choline was with organic matter. Ethanolamine was significantly related to organic matter at the 0.1% level and total phosphorus at the 10% level but the relation was better between ethanolamine and organic matter. Glycerophosphate was significantly related only to organic phosphorus at the 5% level.

Mineralization of organic phosphorus

The net changes in inorganic phosphorus levels after 0, 3, 7, 15, 30 and 60 days from the beginning of incubation are presented graphically in Figs. 1—6. Data presented in Fig.1 indicated that phosphorus mineralization increased

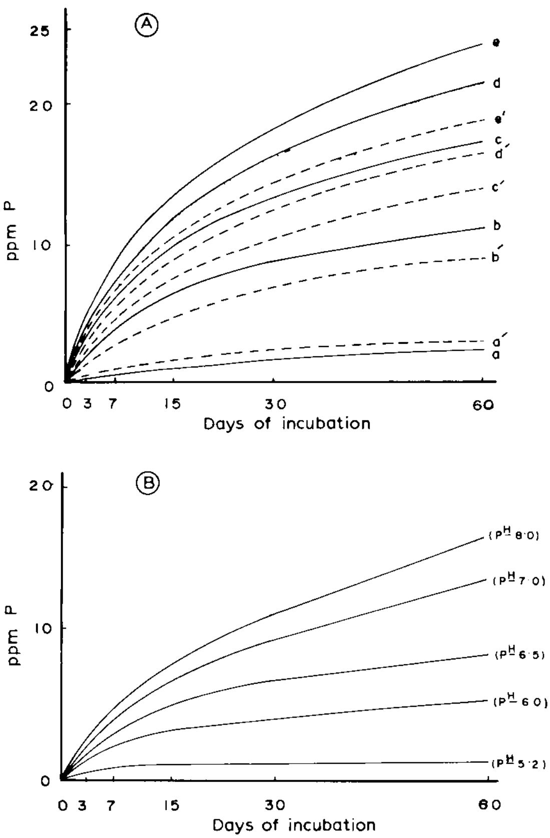

Fig.1. Mineralization of soil organic phosphorus with time: A. as affected by various moisture levels; B. as affected by liming.

Legend: *a*, *a'* = control; *b*, *b'* = 25% field moisture capacity; *c*, *c'* = 50% field moisture capacity; *d*, *d'* = 100% field moisture capacity; *e*, *e'* = submerged condition; ——— Kumira soil; - - - - - Kalma soil.

progressively with incubation time in all treatments but the highest mineralization was observed during the first 15 days. An appreciable amount of organic phosphorus was mineralized in the treatment with moisture alone (Fig.1A). Maximum mineralization took place when the soil samples were submerged. Hayashi and Takijima (1955) had observed earlier that mineralization of organic phosphorus was stimulated by higher moisture levels. Acquaye (1963) also reported that considerable mineralization of organic phosphorus occurred during 70 days of incubation of a soil sample at 50% water-holding capacity. It was observed that at all moisture levels, mineralization was higher in Kumira than in Kalma soil samples (Fig.1). This might be due to higher amounts of organic matter, organic phosphorus, and high pH values of the soil sample (Table II). Alexander (1961) stated that mineralization of organic phosphorus is also related to the quantity of substrate.

Fig.1B indicates that liming increased the mineralization progressively, the highest value being recorded for soil samples with pH 8.0. Raising pH values (8.0 over 5.2 in Fig.2) increased mineralization considerably. Kaila (1948) and Stevenson (1964) observed earlier that the increase in pH value of a sample from acid to neutral increased the release of phosphorus through mineralization. Alexander (1961) and Islam and Ahmed (1973) also report that mineralization is enhanced by adjusting the pH to values conducive to general microbial metabolism and a shift from acidity to neutrality increases phosphorus release.

When each of compost, potassium dihydrogen phosphate, glucose and ammonium sulphate (Fig.2) was added independently with moisture at different

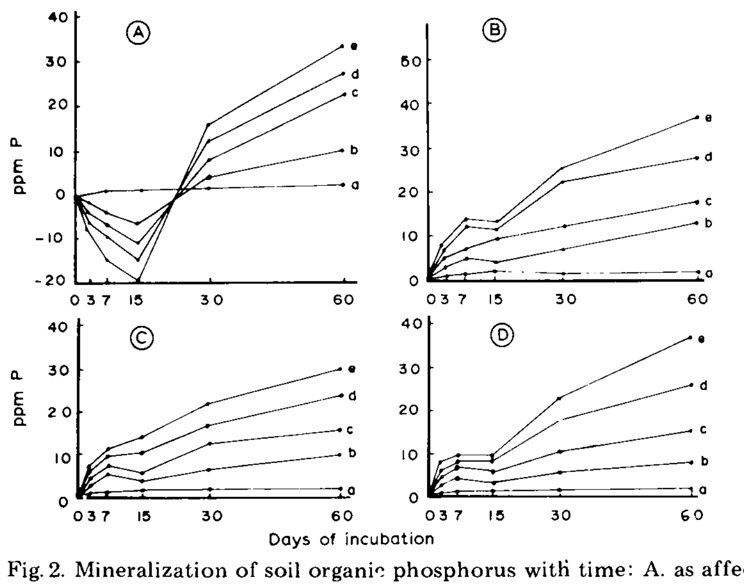

Fig. 2. Mineralization of soil organic phosphorus with time: A. as affected by compost; B. as affected by potassium dihydrogen phosphate; C. as affected by glucose; D. as affected by ammonium sulphate. Legend: see Fig.1.

levels, the nature of mineralization changed. The addition of compost (Fig.2A) caused an initial luxury immobilization for a period of 15 days followed by increased mineralization after 30 days. Enwezor (1967) also reported that application of organic matter caused an initial luxury absorption by micro-organisms. This was followed by enhanced mineralization as incubation proceeded. With potassium dihydrogen phosphate, glucose and ammonium sulphate (Fig.2B—D), however, there was slight mineralization during the initial 7 days. This was followed by a slight decrease up to 15 days, except in two cases (glucose under submerged conditions and potassium dihydrogen phosphate with samples at 50% of field moisture capacity). For all of these treatments, mineralization increased with time.

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