

INOSITOL PHOSPHATE ESTERS IN SOME SURFACE SOILS OF BANGLADESH

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ABSTRACT

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Concentrations of inositol mono-, di- and tri-, tetra-, penta- and hexaphosphate ranged from 5.0 to 12.5, 10.0 to 27.6, 20.0 to 45.0, 22.5 to 64.6, and 20.0 to 275.4 ppm, respectively, in samples of soils that were poorly drained and mostly derived from alluvium. Multiple correlation suggested that the amounts of esters of inositol phosphate other than inositol monophosphate were significantly correlated with organic phosphorus, total phosphorus, organic carbon, total nitrogen, inositol phosphate, clay, exchangeable iron and aluminium, and pH. Individually, inositol hexa-, penta-, and di- and triphosphates were significantly correlated with organic phosphorus, total phosphorus, organic carbon, total nitrogen, inositol phosphate, and exchangeable iron and aluminium; inositol tetraphosphate with organic carbon, total nitrogen, inositol phosphate, and exchangeable iron and aluminium; inositol monophosphate with none.

INTRODUCTION

A significant proportion of the organic phosphorus in soil has been found to occur as inositol phosphate (Cosgrove, 1967). The observed concentrations differed with the type of soil, mode of extraction and presence of other soil constituents (McKercher and Anderson, 1968). Moreover, fractionation studies of hydrolysis products of inositol phosphate indicated that this compound yields six esters (mono- to hexaphosphate of inositol) (Anderson and Malcolm, 1974), but little has been done to estimate their amounts in soils.

An attempt was made to determine the relative amounts of inositol phosphate esters and the relationships of those with selected soil properties in some surface soils of Bangladesh. Amounts of inositol phosphates were also estimated by two different methods.

TABLE I
Identification and physical characteristics of the soil samples

Soil series	USDA soil taxonomy	General type	Parent material	Texture	Drainage	Colour
Karail	Haplaquept	ABC	Madhupur clay alluvium	clay	very poor	grey
Jatrabari	Haplaquept	GFS	Madhupur clay alluvium	clay	poor	olive grey
Siddirganj	Aeric Haplaquept	NDGFS	Old Meghna estuarine	silty clay	poor	dark grey
Kajla	Haplaquept	NDGFS	Gangetic Floodplain	silty clay	poor	grey
Magra	Haplaquept	NDGFS	Old Meghna estuarine	silty clay	poor	dark grey
Harta	Histosol	Peat	Peat	clay	poor	black
Naldanga	Haplaquept	NDGFS	Tista Floodplain	silt loam	very poor	dark grey
Paysa	Typic Haplaquoll	NDGFS	Old Meghna estuarine	silt loam	poor	dark grey
Sarala	Aeric Haplaquept	NDGFS	Tista Floodplain	clay loam	poor	dark grey
Lashkara	Aeric Haplaquept	NDGFS	Old Himalayan piedmont	clay	poor	grey

ABC = acid basin clay; GFS = grey floodplain soil; NDGFS = non-calcareous dark grey floodplain soil.

MATERIALS AND METHODS

Materials

Samples of surface soils (0–15 cm) were collected from three tracts of Bangladesh. The samples were air-dried, ground and passed through a 100-mesh sieve. General descriptions of the samples and classification of the soils according to USDA Soil Taxonomy are presented in Table I. Certain physical and chemical properties of the samples are presented in Table II.

TABLE II

Certain physical and chemical properties of the soil samples

Soil series	pH	Clay <0.002 mm (%)	Org.C (%)	Total N (%)	Org.P. (ppm)	Total P (ppm)	Exchange- able Fe and Al (ppm)
Karail	4.3	60	2.38	0.15	205	445	24.0
Jatrabari	4.5	50	2.39	0.15	180	405	23.0
Siddirganj	4.6	50	2.78	0.17	250	520	20.0
Kajla	4.6	45	2.68	0.18	220	425	30.0
Magra	5.5	25	3.94	0.30	320	500	28.0
Harta	5.8	50	12.94	0.88	560	850	68.0
Naldanga	5.9	65	12.04	0.86	530	780	55.0
Paysa	6.6	55	7.09	0.58	450	680	43.0
Sarala	7.2	55	2.55	0.16	240	505	23.0
Lashkara	7.3	48	3.84	0.27	300	490	35.1

Analytical methods

pH was measured electro-chemically, using a Pye glass electrode, the soil and water ratio being 1:2.5. Analyses were made for organic carbon by Tinsley's wet-combustion method as described by Bremner and Jenkinson (1960); for total nitrogen by the Kjeldahl method; organic and total phosphorus by the method of Mehta et al. (1954); exchangeable iron by the method of Olson (1965); exchangeable aluminium by the method of McLean (1965), and inositol phosphate esters by the method of Anderson and Malcolm (1974). Extraction and estimation of inositol phosphate were by the methods of Anderson (1964) and McKercher and Anderson (1968).

RESULTS AND DISCUSSION

Comparison of methods for determining inositol phosphate

The concentrations of inositol phosphate in the ten samples measured by the above two methods are summarized in Table III. Amounts of inositol phosphate ranged between 93 and 392 ppm by Anderson's procedure and

TABLE III

Inositol phosphates content of soil samples measured by two methods

Soil series	Method of Anderson			Method of McKercher and Anderson		
	ppm	% org.P	% total P	ppm	% org.P	% total P
Karail	102	49.5	22.9	120	58.5	27.0
Jatrabari	94	52.2	24.0	110	61.1	27.2
Siddirganj	152	60.8	29.2	175	70.0	33.7
Kajla	139	63.2	32.7	160	72.7	37.6
Magra	203	63.4	40.6	220	68.8	44.0
Harta	392	70.0	46.1	420	75.0	49.4
Naldanga	322	60.8	41.3	350	66.0	44.9
Paysa	248	55.1	36.5	275	61.1	40.4
Sarala	93	38.8	18.4	110	45.8	21.8
Lashkara	169	56.3	34.0	180	60.0	36.7
Maximum	392	70.0	46.1	420	75.0	49.4
Minimum	93	38.8	18.4	110	45.8	21.8
Mean	191	57.0	32.6	212	63.9	36.3

110 and 420 ppm by McKercher and Anderson's procedure. The values obtained in the present study compared well with the findings of Anderson (1964), Omotoso and Wild (1970) and Islam and Ahmed (1973). The quantities of inositol phosphate determined by Anderson's procedure were slightly lower, presumably because of incomplete precipitation, than those determined by the method of McKercher and Anderson. Anderson (1964) also reported similar amounts of inositol penta- and hexaphosphate in some British soils by these two methods.

Distribution of inositol phosphates

Amounts of inositol mono-, di- and tri-, tetra-, penta-, and hexaphosphate ranged between 5.0 and 12.5, 10.0 and 27.6, 20.0 and 45.0, 22.5 and 64.6, and 20.0 and 275.4 ppm, respectively (Table IV). These components comprised 1.8–10.9, 6.5–15.8, 8.1–29.5, 15.4–27.3, and 18.2–65.6% of the inositol phosphate, respectively, and 1.3–6.7, 4.0–11.0, 5.0–18.1, 9.4–17.3 and 11.1–49.2% of the organic phosphorus contents of the soil samples, respectively.

The amounts are comparable to those obtained by other authors. The lower forms of esters (mono-, di- and triphosphates of inositol) accounted collectively for 11.4–41.1% of the organic phosphorus in some Iowan soils (Bower, 1945) and more than 50% in some Scottish soils (Anderson, 1967). In contrast, lower values of 1–7% in New Zealand soils (Martin and Wicken, 1966), less than 3% in Nigerian soils (Omotoso and Wild, 1970) and about 2.4% in Aberdeenshire soils (Anderson and Malcolm, 1974) have also been reported. Inositol hexaphosphate ranged from 3 to 52% of the organic phosphorus in some British soils (Caldwell and Black, 1958a) and from 26 to 35% in Alberta soils (Thomas and Lynch, 1960).

TABLE IV
Content of inositol phosphate esters in ten Bangladesh soils

Soil series	Inositol phosphate (ppm)	Inositol phosphates esters						inositol hexaphosphate								
		inositol monophosphate		inositol di- and triphosphates		inositol tetraphosphate		inositol pentaphosphate								
		ppm	%*1	%*2	ppm	%*1	%*2	ppm	%*1	%*2						
Karail	120	4.0	3.5	2.0	10.5	8.8	5.0	20.3	16.9	9.7	31.6	26.3	15.0	53.6	44.6	25.5
Jatrabari	110	11.8	10.9	6.7	15.5	14.1	8.6	32.5	29.5	18.1	30.1	27.3	16.7	20.1	18.2	11.1
Siddirganj	175	12.5	7.1	5.0	27.6	15.8	11.0	25.0	14.3	10.0	31.9	18.2	12.8	78.1	44.6	31.2
Kaila	160	9.0	5.6	4.1	15.5	9.7	7.0	35.5	22.2	16.1	38.0	23.8	17.3	62.0	38.8	28.2
Magra	220	10.0	4.5	3.1	25.0	11.4	7.8	35.0	15.9	10.9	37.6	17.0	11.7	112.5	51.1	35.2
Harta	420	7.5	1.8	1.3	27.4	6.5	4.9	45.0	10.7	8.0	64.6	15.4	11.6	275.4	65.6	49.2
Naldanga	350	9.0	2.6	1.7	26.0	7.4	4.9	35.0	10.0	6.6	58.8	16.8	11.1	221.2	63.2	41.7
Paysa	275	7.5	2.7	1.7	18.0	6.5	4.0	22.5	8.1	5.0	52.2	19.0	11.6	174.8	63.6	38.8
Sarala	110	5.0	2.8	2.1	10.0	9.1	4.2	20.0	18.2	8.3	22.5	20.5	9.4	52.2	47.7	21.9
Lashkara	180	10.0	2.9	3.3	17.5	9.7	5.8	22.5	12.5	7.5	35.0	19.4	11.7	95.0	52.8	31.7
LSD at 1% level	9.52	1.51			2.15			2.85			3.51					
Maximum	420	12.5	10.9	6.7	27.6	15.8	11.0	45.0	29.5	18.1	64.6	27.3	17.3	275.4	65.6	49.2
Minimum	110	5.0	1.8	1.3	10.0	6.5	4.0	20.0	8.1	5.0	22.5	15.4	9.4	20.1	18.2	11.1
Mean	212	8.7	4.4	3.1	19.3	9.9	6.3	29.3	15.8	10.0	40.2	20.4	12.9	114.5	49.0	31.5

*1 Percentages were calculated on the basis of inositol phosphates.

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

Correlation between inositol phosphate esters and soil properties

In an effort to understand the differing amounts of these components in soil samples, simple and multiple correlations were calculated with organic phosphorus, total phosphorus, organic carbon, total nitrogen, inositol phosphate, clay, exchangeable iron and aluminium, and pH (Table V). Multiple correlations suggested that all these factors contributed to differing amounts of the esters except inositol monophosphate. Individually, inositol hexa- and pentaphosphates were significantly correlated with organic phosphorus, total phosphorus, organic carbon, total nitrogen, inositol phosphate and exchangeable iron and aluminium at the 0.1% level. Inositol tetrphosphate was significantly correlated with organic carbon, inositol phosphate, and exchangeable iron and aluminium at the 5% level and total nitrogen at the 10% level. Inositol di- and triphosphates together were significantly correlated with organic phosphorus at the 2% level, inositol phosphate at the 1% level, and exchangeable iron and aluminium at the 10% level. Inositol monophosphate was significantly correlated with none of the factors.

Caldwell and Black (1958b) reported that inositol hexaphosphate was associated to some extent with pH, the content of free iron oxide (Fe), and the content of organic phosphorus in forms other than inositol hexaphosphate in soils. Inositol penta- and hexaphosphates together were significantly correlated with both organic and total phosphorus and jointly with organic phosphorus, total phosphorus, organic carbon, total nitrogen and pH of the soil samples (Islam and Mandal, 1977). Inositol hexaphosphate, like orthophosphate, is known to be strongly absorbed by clay minerals and sesquioxides (Anderson and Arlidge, 1962) and its stability is thought to be

TABLE V

Single and multiple correlation coefficients between inositol phosphate esters and various soil properties

Soil factors	Correlation coefficient (<i>r</i>) for different inositol phosphate esters				
	mono	di- and tri-	tetra	penta	hexa
Organic p	-0.110	+0.661* ³	+0.469	+0.908* ⁵	+0.974* ⁵
Total p	-0.153	+0.643* ²	+0.494	+0.942* ⁵	+0.989* ⁵
Organic C	-0.096	+0.626* ²	+0.602* ²	+0.948* ⁵	+0.969* ⁵
Total N	-0.099	+0.617* ²	+0.564* ¹	+0.960* ⁵	+0.974* ⁵
Inositol P	-0.007	+0.727* ⁴	+0.645* ²	+0.967* ⁵	+0.994* ⁵
Clay	-0.395	-0.247	-0.302	+0.191	+0.167
Exchangeable Fe and Al	-0.145	+0.525* ¹	+0.622* ²	+0.953* ⁵	+0.956* ⁵
pH	-0.253	+0.012	-0.250	+0.159	+0.337
All factors	+0.389	+0.885* ⁵	+0.862* ⁵	+0.985* ⁵	+0.998* ⁵

*¹Denotes significance at 10% level; *²denotes significance at 5% level; *³denotes significance at 2% level; *⁴denotes significance at 1% level; *⁵denotes significance at 0.1% level.

associated with that behaviour. Evidence from the present study supports this idea as the esters of inositol, except inositol monophosphate, were significantly correlated with exchangeable iron and aluminium and only the higher esters (penta- and hexaphosphate of inositol) were positively correlated with clay contents of the samples (Table V).

REFERENCES

- Anderson, G., 1963. The effect of iron/phosphorus ratio and acid concentration on the precipitation of ferric inositol hexaphosphate. *J. Sci. Food Agric.*, 14: 352–359.
- Anderson, G., 1964. Investigations on the analysis of inositol hexaphosphate in soils. *Trans. 8th Int. Congr. Soil Sci. (Adelaide)*, 563–572.
- Anderson, G., 1967. Nucleic acids, derivatives, and organic phosphates. In: A.D. McLaren and G.H. Peterson (Editors), *Soil Biochemistry*. Edward Arnold, London, pp. 67–90.
- Anderson, G. and Arlidge, E.Z., 1962. The adsorption of inositol phosphates and glycerophosphate by soil clays, clay minerals and hydrated sesquioxides in acid media. *J. Soil Sci.*, 13: 216–224.
- Anderson, G. and Malcolm, R.E., 1974. The nature of alkali-soluble organic phosphates. *J. Soil Sci.*, 25: 882–897.
- Bower, C.A., 1945. Separation and identification of phytin and its derivatives from soils. *Soil Sci.*, 59: 277–285.
- Bremner, J.M. and Jenkinson, D.S., 1960. Determination of organic carbon in soil. *J. Soil Sci.*, 11: 394–402.
- Caldwell, A.C. and Black, C.A., 1958a. Inositol hexaphosphate. I. Quantitative determination in extracts of soils and manure. *Soil Sci. Soc. Am. Proc.*, 21: 290–293.
- Caldwell, A.C. and Black, C.A., 1958b. Inositol hexaphosphate. III. Content in soils. *Soil Sci. Soc. Am. Proc.*, 22: 296–298.
- Cosgrove, D.J., 1967. Metabolism of organic phosphates in soil. In: A.D. McLaren and G.H. Peterson (Editors), *Soil Biochemistry*. Edward Arnold, London, pp. 216–228.
- Islam, A. and Ahmed, B., 1973. Distribution of inositol phosphates, phospholipids, and nucleic acids and mineralization of inositol phosphate in some Bangladesh soils. *J. Soil Sci.*, 24: 193–198.
- Islam, A. and Mandal, R., 1977. Amounts and mineralization of organic phosphorus compounds and derivatives in some surface soils of Bangladesh. *Geoderma*, 17: 57–68.
- Martin, J.K. and Wicken, A.J., 1966. Soil organic phosphorus. IV. Fractionation of organic phosphorus in alkaline soil extracts and the identification of inositol phosphates. *N.Z.J. Agric. Res.*, 9: 529–539.
- McKercher, R.B. and Anderson, G., 1968. Characterization of the inositol penta- and hexaphosphate fractions of a number of Canadian and Scottish soils. *J. Soil Sci.*, 19: 302–309.
- McLean, E.O., 1965. Exchangeable aluminium. In: C.A. Black, D.D. Evans, L.E. Ensminger, J.L. White and F.E. Clark (Editors), *Methods of Soil Analysis, Part 2*. American Society of Agronomy, Inc., Madison, Wisc., pp. 985–993.
- Mehta, N.C., Legg, J.O., Goring, C.A.I. and Black, C.A., 1954. Determination of organic phosphorus in soils. I. Extraction method. *Soil Sci. Soc. Am. Proc.*, 18: 443–449.
- Olson, R.V., 1965. Exchangeable iron. In: C.A. Black, D.D. Evans, L.E. Ensminger, J.L. White and F.E. Clark (Editors), *Methods of Soil Analysis, Part 2*. American Society of Agronomy, Inc., Madison, Wisc., pp. 967–968.
- Omotoso, T.I. and Wild, A., 1970. Content of inositol phosphates in some English and Nigerian soils. *J. Soil Sci.*, 21: 216–223.
- Thomas, R.L. and Lynch, D.L., 1960. Quantitative fractionation of organic phosphorus compounds in some Alberta soils. *Can. J. Soil Sci.*, 40: 113–120.