

Short communication

Quantification and bioavailability of *scyllo*-inositol hexakisphosphate in pasture soils

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Received 16 September 2004; received in revised form 28 February 2005; accepted 16 March 2005

Abstract

The recent identification of *scyllo*-inositol hexakisphosphate in alkaline soil extracts by solution ³¹P NMR spectroscopy allowed us to investigate this compound in soils by re-analyzing spectra from two previously published studies. Concentrations of *scyllo*-inositol hexakisphosphate in 29 temperate pasture soils from England and Wales ranged between 11 and 130 mg P kg⁻¹ soil and accounted for between 4 and 15% of the soil organic phosphorus. The ratio of *scyllo*-inositol hexakisphosphate to *myo*-inositol hexakisphosphate ranged between 0.29 and 0.79. In a 10 month pot experiment with six grassland soils from New Zealand, growth of pine seedlings (*Pinus radiata* D. Don) decreased *scyllo*-inositol hexakisphosphate concentrations by between 10 and 46%. Growth of ryegrass (*Lolium perenne* L.) decreased *scyllo*-inositol hexakisphosphate in three low-nutrient soils by 5–21%, but increased it in three other soils by 11–16%. We conclude that *scyllo*-inositol hexakisphosphate is an important component of soil organic phosphorus with potential ecological significance. © 2005 Elsevier Ltd. All rights reserved.

Keywords: Pasture soil; Inositol phosphate; *myo*-Inositol hexakisphosphate *scyllo*-inositol hexakisphosphate; Phytic acid; Solution ³¹P NMR spectroscopy

Most soils contain *scyllo*-inositol phosphates, yet quantitative data is scarce due to the analytical difficulties involved in their determination (Turner et al., 2002). This is unsatisfactory given the importance of soil organic phosphorus in plant nutrition and biogeochemical cycles (Condon et al., 2005). We used the recent identification of *scyllo*-inositol phosphates in alkaline soil extracts by solution ³¹P NMR spectroscopy (Turner and Richardson, 2004) to re-analyze spectra from two published studies. Our aim was to quantify *scyllo*-inositol hexakisphosphate in permanent lowland pasture soils and to assess its potential bioavailability to growing plants.

The first study involved 29 permanent pasture soils from England and Wales (Turner et al., 2003a). The soils were acidic (pH 4.4–6.8) and contained a wide range of clay (22–68%), carbon (2.9–8.0%), nitrogen (0.28–0.87%),

and phosphorus (0.04–0.20%) concentrations. Organic phosphorus determined by NaOH–EDTA extraction and solution ³¹P NMR spectroscopy ranged between 0.02 and 0.09%. We previously reported the phosphorus composition of these soils (Turner et al., 2003a), including concentrations of *myo*-inositol hexakisphosphate (Turner et al., 2003b).

The second study involved a pot experiment with six New Zealand grassland soils in which either ryegrass (*Lolium perenne* L.) or pine seedlings (*Pinus radiata* D. Don) were grown for 10 months (Chen et al., 2004). The soils were acidic (pH 5.2–6.5) with relatively small amounts of clay (11–26%), but contained a wide range of carbon (3.9–9.3%), nitrogen (0.31–0.85%), and phosphorus (0.04–0.27%) concentrations. Organic phosphorus determined by NaOH–EDTA extraction and solution ³¹P NMR spectroscopy ranged between 0.02 and 0.07%. One soil from the original study (Hurunui) was not included here, because spectral deconvolution data was not available.

In both studies, phosphorus was extracted in a solution containing 0.5 M NaOH and 50 mM EDTA (ethylenediaminetetraacetate) and analyzed by solution ³¹P NMR

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Table 1

Concentrations of *scyllo*-inositol hexakisphosphate in lowland permanent pasture soils from England and Wales and the ratio of *scyllo*-inositol hexakisphosphate to *myo*-inositol hexakisphosphate

Soil series	<i>scyllo</i> -inositol hexakisphosphate		<i>scyllo</i> -to- <i>myo</i> ratio
	mg P kg ⁻¹ soil	% Organic P ^a	
1. Brockhurst	33	8.0	0.34
2. Dunkswick	21	8.2	0.45
3. Wick	35	12.9	0.79
4. Denbigh	50	10.4	0.35
5. Nupend	23	6.7	0.29
6. Brickfield	43	13.8	0.40
7. Dunkswick	12	5.5	0.43
8. Brickfield	24	10.8	0.39
9. Whimble	19	8.9	0.71
10. Salop	36	8.4	0.40
11. Whimble	33	8.7	0.38
12. Newport	59	13.5	0.42
13. Denbigh	48	11.3	0.49
14. Clifton	27	8.7	0.33
15. Brickfield	59	10.8	0.41
16. Wick	52	11.1	0.37
17. Brickfield	30	6.3	0.41
18. Oxpasture	59	14.2	0.63
19. Whimble	37	10.3	0.44
20. Hallsworth	39	9.3	0.49
21. Brickfield	30	10.8	0.40
22. Moor Gate	51	11.1	0.49
23. Denbigh	130	14.5	0.69
24. Nordrach	52	10.9	0.31
25. Newchurch	11	4.4	0.32
26. Denchworth	30	7.9	0.47
27. Worcester	30	7.5	0.36
28. Whimble	33	6.7	0.59
29. Fladbury	77	8.7	0.47
Mean	41	9.7	0.45

The soils are ranked in order of their total carbon content and the soil numbers correspond to those used in Turner et al. (2003a, b).

^a Organic phosphorus was the sum of phosphonates, phosphate monoesters and phosphate diesters determined by NaOH–EDTA extraction and solution ³¹P NMR spectroscopy (Turner et al., 2003a).

spectroscopy. We identified *scyllo*-inositol hexakisphosphate in re-analyzed spectra as the signal appearing close to 4.2 ppm following spectral deconvolution (Turner and Richardson, 2004). Concentrations were calculated by multiplying the proportion of the spectral area assigned to *scyllo*-inositol hexakisphosphate by the total phosphorus concentration of the initial extract.

In the 29 pasture soils from England and Wales, concentrations of *scyllo*-inositol hexakisphosphate ranged between 11 and 130 mg P kg⁻¹ soil (mean 41 mg P kg⁻¹ soil) (Table 1). These values represented between 1.4 and 8.4% of the total soil phosphorus (mean 4.3%) and between 4.4 and 14.5% of the organic phosphorus extracted in NaOH–EDTA (mean 9.7%) (Table 1). As a proportion of the phosphate monoesters, *scyllo*-inositol hexakisphosphate constituted between 5.0 and 16.2% (mean 10.8%). Concentrations were smaller than those of *myo*-inositol hexakisphosphate calculated by the same procedure, which ranged between 26 and 189 mg P kg⁻¹ soil (mean 93 mg P kg⁻¹ soil) and between 11.2 and 35.0% (mean 22%) of the organic phosphorus extracted in NaOH–EDTA (Turner et al., 2003b). The ratio of *scyllo*-inositol hexakisphosphate-to-*myo*-inositol hexakisphosphate ranged between 0.29 and 0.79 (mean 0.45).

Concentrations of *scyllo*-inositol hexakisphosphate were correlated positively with those of organic phosphorus and *myo*-inositol hexakisphosphate and negatively with the carbon-to-organic phosphorus and nitrogen-to-organic phosphorus ratios (Fig. 1). Concentrations were also correlated positively with NaHCO₃-extractable organic phosphorus ($p < 0.01$; model not shown). However, there were no other significant correlations ($p > 0.05$) between *scyllo*-inositol hexakisphosphate and soil physical and chemical properties, including total carbon and nitrogen, oxalate-extractable metals, the degree of phosphorus saturation, clay, or microbial nutrients. The ratio of *scyllo*-inositol hexakisphosphate-to-*myo*-inositol hexakisphosphate was not correlated significantly with any soil property measured ($p > 0.05$).

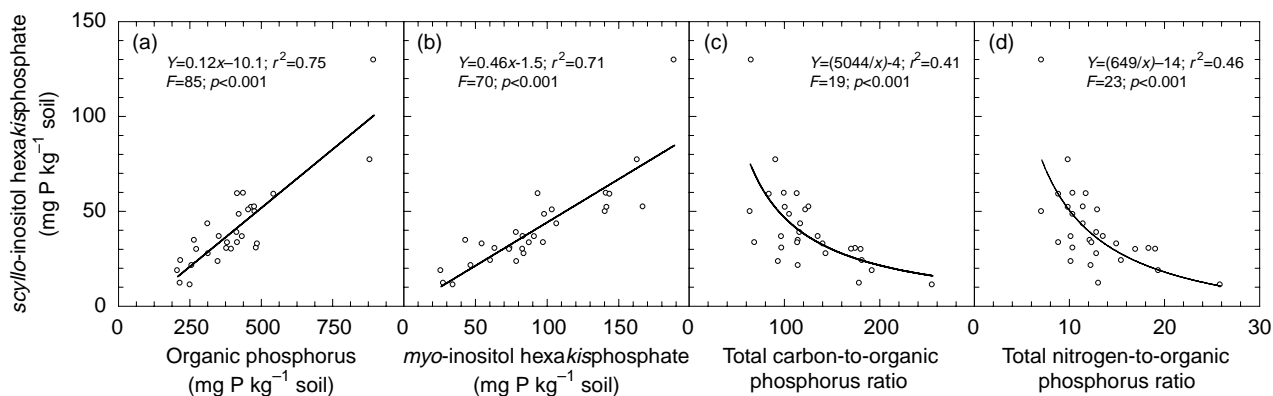


Fig. 1. Relationships between *scyllo*-inositol hexakisphosphate and (a) NaOH–EDTA extractable organic phosphorus, (b) *myo*-inositol hexakisphosphate, (c) the carbon-to-organic phosphorus ratio, and (d) the nitrogen-to-organic phosphorus ratio.

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