PATHWAYS FOR LOSSES OF PHOSPHORUS FROM RAINFED PASTURES IN SOUTH AUSTRALIA

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ABSTRACT

This study showed that significant amounts of phosphorus (P) applied to grasslands in the Adelaide hills, South Australia move through kaolinitic clay subsoils. Large undisturbed soil cores were collected down a hillslope with soils and pasture typical of the Adelaide hills. Fertiliser was added to the surface of soil cores and catchment rainfall simulated. Leachate from the cores was measured daily and analysed for P. Results showed up to 34% of P applied to pastures on the upper-slopes, moves vertically through the subsoil clays mostly in the dissolved form. Elsewhere, < 1% of the applied P was lost. The subsoils where P movement was significant had high clay (44%) and iron oxide content (14%). These subsoils also had the greatest number of macropores (20% of pores > 5 mm). The results showed the importance of macropore flow in the loss of P from these grasslands.

KEYWORDS

Phosphorus leaching, macropore flow, texture-contrast soils, drainage

INTRODUCTION

The majority of soils cleared by pastoralists in South Australia for sheep, beef and dairy cattle are loams over clays (texture-contrast soils; Chittleborough, 1992). Phosphatic fertilisers applied to grasslands have resulted in high phosphate levels in waterways and eutrophication in water storages (Pilgrim, 1986). The current view for the origin of the phosphorus (P), for all but sandy soils, is that it is from the soil surface and enters the waterways in overland flow (Ozanne *et al*., 1961; Mansell *et al*., 1977; Peverill *et al*., 1977; Sharpley *et al*., 1993). It is also thought that, provided the soil reservoir of soluble P is unsaturated, P will not leach more than a few centimetres into a soil profile that contains significant amounts of clay due to time-dependent adsorption and fixation processes, mainly at the surfaces of iron and aluminium oxides (Rajan *et al*. 1974; Rolston *et al*., 1975; Bolt, 1976). Exceptions may occur in peats or other soils with a high organic content where soluble organic matter can facilitate the transport of P in subsurface flow by coating the active sites for P adsorption (Pierzynski *et al*., 1994). The aim of this research was to determine if P moves vertically through the clay subsoils of texture contrast soils in the Adelaide hills and thus potentially contribute to P in waterways.

METHODS

Duplicate 300 mm diameter undisturbed soil cores were drilled using the method of Kirkby *et al*. (1996) from a toposequence in the Keynes catchment in the Adelaide hills. The A horizon soil cores were prepared by picking back the B horizon until only the natural ped face of the A horizon remained. The core base was then vacuumed to remove loose soil aggregates to minimise any subsequent pore clogging. A 5 mm wide and 10 mm deep groove was cut around both the top and bottom edge of the core and filled with liquid vaseline to prevent edge flow between the pipe and the soil. The base of the core was filled with acid-washed coarse sand over which a layer of mesh was placed and then capped, leaving a hole over which a funnel was placed to collect the leachate (Figure 1). The A+B horizon soil cores were prepared in the same manner except that the C horizon material was picked back until only a natural ped face of the B horizon remained. The equivalent of 15 kg/ha of P in the form of triple phosphate [80% $Ca(H_2PO4)_2.H_2O$] was applied to the surface of each core. Irrigation was via a variable speed peristaltic pump connected to a perspex box with 187 hypodermic needles inserted at regular intervals in the base. Rainfall was simulated by irrigating the cores for 1 hr per day at an intensity of 20 mm/hr for 5 consecutive days each week for 5 weeks giving a total of 25 irrigation days over the duration of the leaching. Leachate was collected daily and analysed for particulate and dissolved (<0.45 µm) P. The pH, electrical conductivity (EC), exchangeable sodium percentage (ESP), iron oxide content (hematite + goethite), saturated hydraulic conductivity (K_{sat}) of the A and B horizons, bulk density (P_b) and clay percentage was measured for the A and B horizon of each core.

RESULTS AND DISCUSSION

Leachate began from the upper-slope cores after 1 day compared with 5 days for cores from the footslope. Thus flow paths were different between soils from the upper-slope and elsewhere in the toposequence. The highest concentration of P was in leachate from the A horizon cores on the upper-slope (47%; P applied less native P from a control core with no added P) and systematically decreased down the slope to 3%. The concentration of P in the leachate from the A+B horizon cores from the upper-slope was high (34%) and 72% moved through the A horizon core. The amount of P recovered in the leachate from the other A+B horizon cores did not differ significantly from those amounts recovered from the control core. Over half (62%) of the native P that was leached from the control core was dissolved. This contrasted with the leachate from the treatment cores in which almost all P was in the dissolved form regardless of position on the toposequence. Thus the P fraction of triple P is readily soluble upon wetting and a heavy rainfall event is probably sufficient to transport environmentally significant amounts of P in the dissolved form, vertically through the A horizon and, on the upper-slope, through the B horizon as well.

There were no general trends in either the physical or chemical properties of the soils along the toposequence other than macroporosity (Table 1). K_{sat} values of the A and B horizons were 0.1 and 0.07 m/day respectively on the upper-slope and similar sets of values were obtained elsewhere along the toposequence. Thus P movement was not related to K_{sat}. Clay content of the A and B horizons was 11 and 47% respectively on the upper-slope where P movement was highest and 11 to 15 and 27 to 43% elsewhere on the toposequence. P_b's of the A and B horizons were 1.34 and 1.76 g/cm^3 respectively on the upper-slope and 1.3 to 1.43 and 1.7 to 1.85 g/cm^3 elsewhere. Iron oxide percentages were similar (9 to 16%) in all profiles except the footslopes where iron had been removed under aquic conditions. ESP of the subsoils was 4.1 to 5.3% on the upper to mid-slope positions and 8% elsewhere. Higher sodicity on the lower slopes could account for the longer time for leachate to drain from these soil cores. Only macroporosity of the B horizon was vastly different down the toposequence. Macroporosity was highest (20% > 5 mm diameter) in the upper-slope soils and least (20% < 2 mm) on the soils of the footslopes.

In conclusion, it has generally been thought that the dominant mechanism of P transport from grasslands in South Australia was via surface flow. However, this study has found that the amount of P the subsoil clays (and probably to groundwaters) on the crests and upper hillslopes of their farms. This is due to macropore flow. Elsewhere, P was mostly attenuated by the subsoil clays.

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Table 1
P leached through soil cores over 25 days and key soil properties

Slope position	P_A	P_B	M_{pore}	C	ESP	Clay	K_{sat}	P_b	Fe
	%	%	20%	%	%	%	m/day	g/cm^3	%
Upper	46.6	33.7	>5mm	0.6	4.1	44	0.065	1.76	11
Mid	15.4	0	2-5 mm	0.4	5.3	36	0.081	1.75	9
Lower	5.6	0.5	2-5 mm	0.6	8.0	43	0.055	1.85	16
Foot	3.0	1.0	< 2mm	0.5	8.0	26	0.022	1.72	0

P_A,P_B :100 [P recovered from the leachate of the A or B horizon cores, respectively - P recovered from the control (no added P)/P applied (100 mg)];

M_{pore} : common macropore size in the B horizon;
C : carbon content of the B horizon;
ESP : exchangeable sodium percentage of the B horizon;
Clay : clay content of the B horizon,
K_{sat} : saturated hydraulic conductivity of the B horizon,
P_b : bulk density of the B horizon;
Fe : percentage iron oxide content of the B horizon.

Figure 1
Set-up of large undisturbed soil cores.