Forms of Soil Phosphorus Accumulation in Grassland Soils

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Introduction

Australian soils are generally low in phosphorus (P) by world standards and require applied P to reduce this limitation on plant growth. In grazing systems P is deposited on the soil surface from fertiliser, livestock excretion and senescing pasture. Phosphate occurs in many forms in soils. Because of rising fertiliser prices there is growing interest in assessing and improving the availability of accumulated soil P.

The objective of the research described here was to identify and quantify the forms of P in soils under permanent grasslands with a wide range of soil P status.

Methods

Site selection and soil sampling

Four farms within 10 km of each other were selected for this study and are located approximately 50 km south-west of Sydney, NSW. Average long-term rainfall for the nearest long-term weather station (<10 km) is ~700 mm, with some sites being irrigated. All sites were under permanent pasture, ranging from naturalised species on the lower fertility sites through to Perennial ryegrass (*Lolium perenne* L) on the higher fertility sites.

Composite soil samples from eighteen paddocks on the four farms were collected (0-10 cm). The soils were all Chromosols (Isbell 2002) or Haploxeralfs (Soil Survey Staff 1999) located in mid-slope positions and were derived from Wianamatta shales.

Phosphorus form identification and quantification

Total soil P and inorganic and organic P contents were determined using the acid extraction and ignition methods of Saunders and Williams (1955). For characterisation of organic P species, 2.0 g of soil was shaken with 40 mL of 0.25 M NaOH and 0.05 M Na_2EDTA for 16 h and subsequently filtered and freeze dried. The relative concentrations of P species in the NaOH-EDTA extracts were determined from ^{31}P NMR spectra using a combination of integration and deconvolution as described in Doolette *et. al*. (2011b) The absolute concentration of each P species was calculated by multiplying its relative contribution to total NMR signal by the total NaOH-EDTA extractable P concentration determined by ICP-AES.

Results

The soils all had clay loam textures with pH (in $CaCl_2$) of 5-5.5. Soil organic carbon (OC) ranged from 2.8 to 7.2% and total P contents ranged from 339-2115 mg/kg. Soil OC was positively correlated with total soil P (P<0.01) and total N (P<0.01). The low P soils at each of the sites have had little or no P inputs whereas the high P soils have typically had large applications of inorganic fertiliser and have been heavily stocked. At low total P concentrations, organic P is the dominant form (typically >75%) of soil P (Fig. 1). However as total soil P concentration increases,

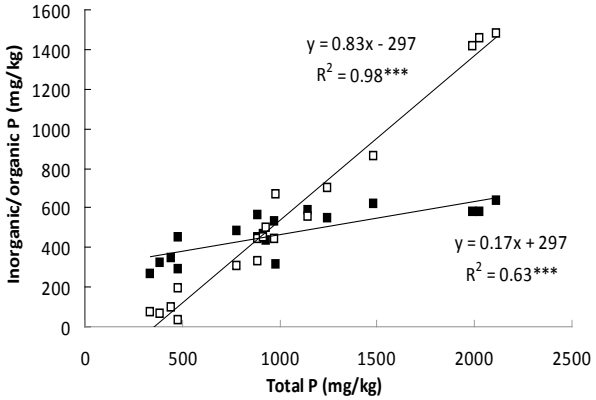

Figure 1. Comparison of inorganic (□) and organic (■) P forms with increasing soil P status.

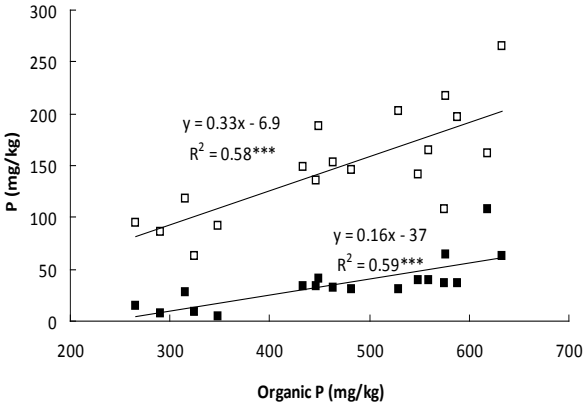

Figure 2. Changes in the quantities of humic (□) P and non-humic (■) P as soil organic P increases.

the majority (average 83%) of soil P accumulates as inorganic P. This data suggests that on low fertility soils, organic P is indeed the dominant form of soil P, but relatively little of the added P accumulates as organic P.

Of the organic P that accumulates, our fractionation showed that it is predominantly in humic forms (Fig. 2). Of the non-humic P, phytate comprised from 0-50% (average 22%). Much attention has focussed on the study and importance of phytate as a form of organic soil P. However, a recent re-examination of the techniques for identifying organic P species in soils (Doolette *et al*. 2011a) raises questions about the prevailing organic P paradigm. This is likely to have implications for the development of strategies for accessing accumulated soil P.

Conclusion

The dominant form of P that accumulates in the soils we studied is inorganic. On low P soils, the dominant form is organic P, the majority of which we characterise as humic P. It is these low P soils that are of most interest from the perspective of releasing stored soil P and the knowledge generated in this study will help to inform future research on this subject. Further study of soil P forms using similar approaches is required on a more diverse set of soils.

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