SHORT NON-REFEREED PAPER

PHOSPHORUS MANAGEMENT IN THE SUGAR INDUSTRY: USING SOIL TESTS TO MINIMISE ENVIRONMENTAL IMPACTS

MILES N[1,2] AND VAN ANTWERPEN R[1,3]

[1]*South African Sugarcane Research Institute, P/Bag X02, Mount Edgecombe, 4300, South Africa*
[2]*School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, P/Bag X01, Scottsville, 3610, South Africa*
[3]*Department of Soil, Crops and Climate Sciences, University of the Free State, PO Box 339, Bloemfontein, 9300, South Africa*

neil.miles@sugar.org.za

Phosphorus (P) is the most limiting nutrient in terms of the eutrophication of most stream and dam waters. Where soil P levels are not excessive, P applied to agricultural land is rapidly immobilized through chemical reactions with soil components, and the potential for pollution is low. With increasing saturation of soils with P, however, extractable (soil test) and soluble P levels increase sharply, with a concomitant increase in the risk of diffusive P loss in overland water flow. Data presented in this paper show that soil test P levels in many fields of the sugar industry are well in excess of established threshold levels for optimum growth, with excess P often being associated with the long-term use of poultry manure. Relationships developed between soluble P (i.e. the P potentially removable in percolating or runoff waters) on the one hand, and P extracted with the Truog and resin tests on the other, reflect an exponential increase in P solubility with rising P test levels beyond the zone of immediate crop growth requirements for this nutrient. A model using resin P / oxalate Al was found to provide an improved prediction of soluble P levels. Of concern is that soil samples taken to a depth of 20 cm for routine soil fertility evaluations in most cases grossly underestimate the P environmental hazard, since P levels are highest at the immediate soil surface (top 2-5 cm soil layer). Based on the findings presented here, suggestions for the more responsible management of P are proposed.

Keywords: phosphorus, environmental pollution, soil testing, soil sampling

Introduction

In recent times, an ever-increasing focus on the environmental impact of agricultural operations emphasises the need for the rigorous application of best management practices. In terms of supplying the nutrient requirements of crops, a particular concern relates to phosphorus (P) management, since the transport of P from agricultural soils to freshwater bodies promotes their eutrophication, which limits water use for drinking, recreation and industry.

The potential for P removal in percolating or runoff waters is closely related to soil properties and labile P levels. It is well established that concentrations of P in runoff and drainage waters increase as soil P status increases (Hedley *et al*., 2002; Vadas *et al*., 2005). Reports indicate that, where the concentrations of dissolved inorganic P in field runoff rise above 0.01 mg P/L, accelerated algal growth may be stimulated in receiving waters (Vollenweider, 1968).

Wide textural and mineralogical heterogeneity in soils of the southern African sugar industries implies massive variations in P retention (Poswa *et al*., 2014), and hence in the potential for P loss. Of particular concern is the likelihood of P pollution from the many fields in the industry that have historically received P applications well in excess of crop requirements (van der Laan and Miles, 2010).

In this paper, relationships between agronomic soil test P values and soluble P in samples drawn from field trials and production fields are presented. Aspects of concern are highlighted, and suggestions for the more responsible management of P are proposed.

Methodology

Topsoil samples for the investigation were drawn from the long-term BT1 trial located at the South African Sugarcane Research Institute (SASRI) in Mount Edgecombe, and also from other crop nutrition trials from various localities in the rainfed industry in South Africa. Also included were 163 topsoils (0-20 cm) from throughout the southern African sugar producing areas (including 10 from Malawi and Zambia), and a selection of topsoils from the Midlands North region which had variable long-term histories of poultry manure applications.

Plant available P was estimated using the Truog (0.02 N H_2SO_4) and resin (overnight equilibration in water of bicarbonate saturated resin strips) tests. Soluble P was estimated by 2 h extraction in 0.01 M $CaCl_2$.

Results and Discussion

The relationship between calcium chloride soluble and soil test P was found to be highly dependent on soil properties, with poorly-buffered sandy soils supporting substantially higher soluble P levels within a particular P test range than more highly buffered soils (Figure 1a). The relationships between calcium chloride soluble P on the one hand, and resin and Truog P test levels on the other, in the 163 industry topsoils were weak (R^2=0.50 for resin, and 0.13 for Truog). Previous work has shown that oxalate extractable Al levels are closely correlated with P sorption in soils of the sugar industry (Poswa *et al*., 2014), and a model using resin P values divided by oxalate Al was found to provide an improved prediction of soluble P levels (Figure 1b). Mid-infrared spectroscopy has been shown to provide reasonably reliable predictions of oxalate Al (Mathadeen *et al*., 2013), and this model could therefore be used on a routine basis for identifying soils with excessively high P levels in the sugar industry's Fertiliser Advisory Service (FAS) laboratory.

With applied P being highly immobile in all except very sandy soils, distinct P stratification is apparent in the soil profiles of most agricultural fields. Investigations carried out in the BT1 trial provide evidence of this phenomenon: the mean resin P values for 0-2 cm depth samples were approximately two-fold those in samples taken to a depth of 10 cm (Figure 2a). In the sugar industry, soil samples for routine soil fertility testing are taken from the 0-20 cm layer. Since surface runoff interacts with only the top few centimetres of soil, data from 0-20 cm samples would underestimate the threat of environmental pollution. There is clearly, therefore, a need for sampling to shallower depths to improve assessments of P available to runoff. In light of the marked stratification of both P and K in soils under advanced ratoons, it appears likely that samples taken to shallower depths may, in any event, more accurately reflect available nutrient reserves than the 0-20 cm samples. This aspect warrants further investigation.

Evidence of overloading of soils with P is of increasing concern. Data presented in Figure 2b show the relationships between Truog P and soil volume weight (VW) for samples submitted from a selection of manure and non-manure using farms in the Midlands North region of the industry. With the agronomic optimum P level being in the range 10 to 18 mg/L, the P excesses in these soils, and in particular those receiving manure, are striking. The positive relationships with VW reflect the more rapid build-up of available P reserves in sandy, low organic matter soils with low P retention.

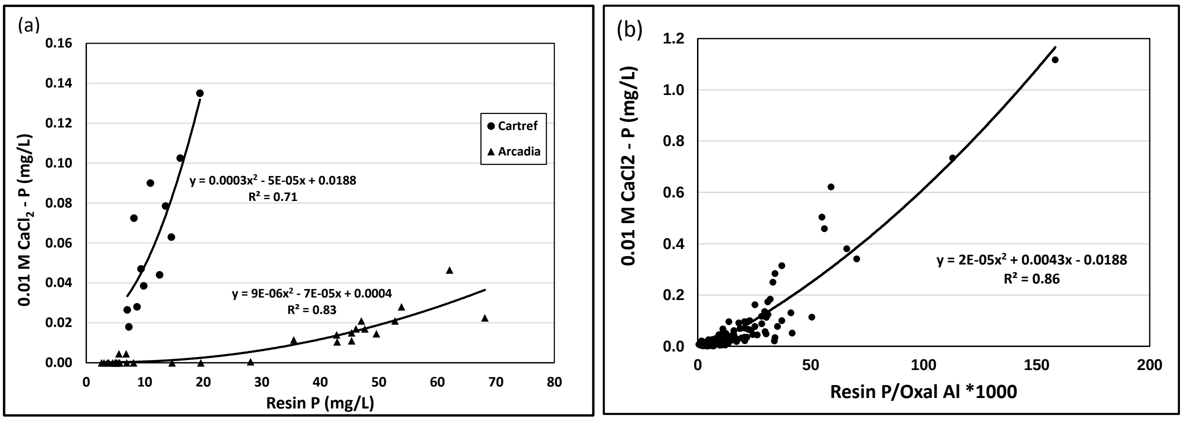

Figure 1. Relationships between (a) resin soil test P and calcium chloride soluble P for Cartref (8% clay, Midlands) and Arcadia (48% clay, North Coast) soils, and (b) resin P/oxalate Al and calcium chloride soluble P for 163 soils from southern African sugar producing fields.

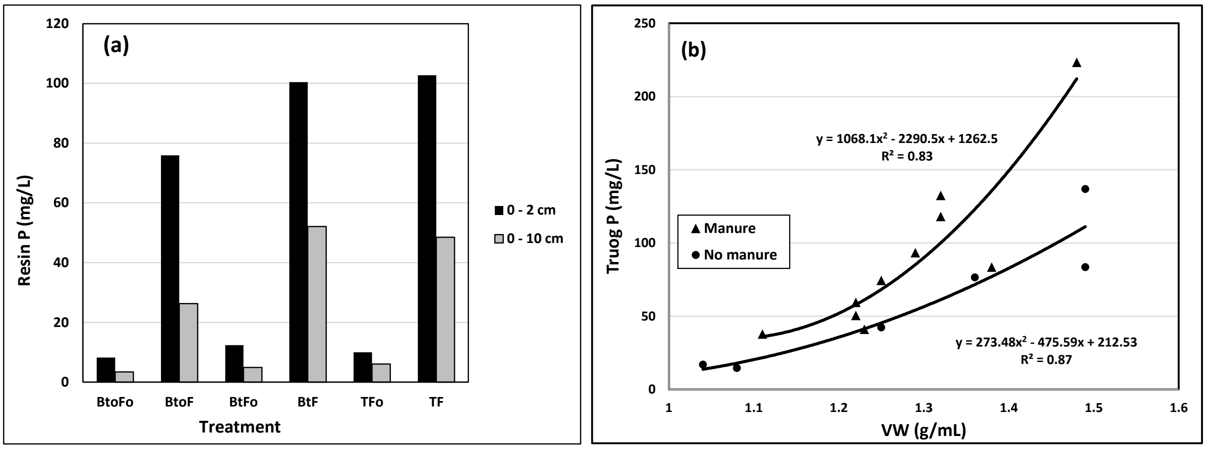

Figure 2. Relationships between resin P soil tests for the 0-2 and 0-10 cm soil sampling depths for individual treatments in the long-term BT1 trial (a), and (b), relationships between the Truog P test and disturbed volume weight (VW) for farms with and without long-term histories of poultry manure use in the Midlands North (sampling depth 0-20 cm; data averages for farms over the period August 2011 to February 2015). (Treatments in the BT1 trial; BtoFo, burned, tops not spread, no fertiliser; BtoF, burned, tops not spread, plus fertiliser; BtFo, burned, tops retained and spread, no fertiliser; BtF, burned, tops retained and spread, plus fertiliser; TFo, residues retained and spread, no fertiliser; TF, residues retained and spread, plus fertiliser).

Conclusions

Clearly, relative to the Truog test, the resin test better represents the likelihood of P release from soil to runoff for the highly heterogeneous soils of the southern African sugar industries. However, the relationship between soil-test P and soluble P is dependent on P sorption characteristics of soils, and for this reason a model which includes oxalate-extractable Al provides more reliable predictions of soluble P than the resin test values on their own.

The fact that soil samples taken to a depth of 20 cm for routine soil fertility evaluations potentially provide a gross underestimate of the P environmental hazard points to a need for a re-evaluation of soil sampling protocols in the industry. Furthermore, widespread evidence of the ‘overloading’ of soils with P, apparently exacerbated by the continued use of poultry manure, is an issue requiring attention.

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