SHORT NON-REFEREED PAPER

PREDICTION OF FERTILISER PHOSPHORUS REQUIREMENT FACTORS FOR SOILS OF THE SOUTHERN AFRICAN SUGAR INDUSTRY

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Abstract

Establishing the phosphorus (P) requirements of sugarcane in southern Africa presents particular challenges for agronomists, since not only is P the most expensive of the macro-nutrients, but wide variations in soil properties imply variable availability of applied P for crop uptake. Of crucial importance in extending advice on P fertilisation is knowledge of the amount of P required under field conditions for unit increase in P soil test. In this study, laboratory incubations were used for quantifying the fertiliser P requirement factors (PRFs) of 40 topsoil samples taken from fields of the South African sugar industry. These soils varied widely in texture (7-47% clay), organic carbon (0.44-9.72%) and pH (3.79-6.65; measured in 0.01 *M* $CaCl_2$). Soils from each site were treated with three levels of P and taken through wetting and drying cycles over a six-week period. Three P-test methods (Truog, Mehlich III and Resin) were included, and the reciprocals of isotherm slopes used to establish PRFs of the soils. PRF values for these three extractants ranged from 2.26-22.52, 1.89-27.17 and 4.39-39.68 kg P/ha per mg P/L, respectively, and were poorly related to clay content, but well related to ammonium oxalate extractable Fe and Al, organic carbon and volume weight (soil sample density). Mid-infrared spectroscopy (MIR) provided useful predictions of PRF values.

Keywords: P soil tests, fertiliser P requirement factors, phosphorus sorption, mid-infrared spectroscopy

Introduction

Managing phosphorus (P) supplies to the sugarcane crop presents particular challenges for agronomists, since not only is P the most expensive of the macro-nutrients, but wide variations in soil properties greatly complicate the process of accurately estimating fertiliser P requirements. The sorption of phosphate by oxides of iron and aluminium and amorphous materials in soils contributes to reduced plant availability of added P, thereby necessitating larger applications of fertiliser P to achieve satisfactory yields (Warren, 1994). It is generally agreed that the higher the clay content within any soil group, the higher is the P fixation (Johnston *et al*., 1991).

The normal approach to correcting P deficiencies is to (i) determine the 'available' soil P level using a specific soil test extractant, and (ii) from the known optimum level applicable to

the particular crop and extractant (established through field trial calibration studies), establish the deficit in terms of the test value. This deficit is converted into a mass of nutrient required per unit area by multiplying it by a conversion factor reflecting soil properties and depth of incorporation of the fertiliser (i.e. the P requirement factor, or PRF). Thus:

Field P requirement (kg/ha) = (optimum soil P – measured soil P) x PRF.

PRF is therefore a soil specific factor which represents the amount of P required per ha for unit increase in P level for a particular soil test. For a given soil P-test, PRF has been shown to vary widely across different soils. Johnston *et al*. (1991), found that the range in PRF values for the three extractants, Ambic II, Bray I and Truog, was 2.5-37.9; 2.0-17.7; and 2.3-30.3 kg/ha, respectively. These authors also reported that the level of P sorption was strongly related to clay content and the presence of 2:1 mineral clays.

The objectives of this study were, firstly, to determine PRF values for three extractants for representative soils of the sugar industry, and secondly, to evaluate the use of mid-infrared spectroscopy for the routine prediction of PRF values.

Materials and Methods

Investigations were carried out on 40 topsoil (0-200 mm) samples taken from fields located throughout the South African sugar industry. These soils ranged in clay content from 7 to 47%, in organic carbon from 0.44 to 9.72% and in pH ($CaCl_2$) from 3.79 to 6.65.

For the determination of PRFs, 1.5 L samples of each soil were treated with three different levels of KH_2PO_4 (0, 50 and 100 mg P/L). Soils were brought to field capacity by adding distilled water and were incubated for six weeks. Re-wetting to field capacity took place every fortnight. Following incubation, soils were air-dried, milled (<1 mm) and tested for P. PRF values were determined from the inverse of the slope of the regression of soil test P against applied P (slopes of all functions were linear or near-linear).

Truog P was determined by extracting with 0.02 *N* H_2SO_4 for 20 minutes (1:50 soil:solution). Resin extractable P was determined as follows: anion exchange resin strips (Ionics AR103QDP), in the HCO_3^- form, were shaken in deionised water with soil for 16 hours (1:20 soil:solution). The P was eluted from the resin strips by shaking for 90 minutes with 1 *M* HCl. Mehlich III was determined by extracting with dilute acid-fluoride-EDTA solution for five minutes (1:10 soil:solution) (Mehlich, 1984). Truog P and Mehlich III P were determined colorimetrically and resin P by ICP.

In the P fixation (sorption) investigation, two 'single-point' indices were compared: the Reeve and Sumner (1970) Bray II (0.02 *N* NH_4F + 0.02 *N* HCl) P desorption index (PDI) (overnight equilibration with a 200 mg/L P solution), and the Bache and Williams (1971) P sorption index (PSI) (18 h equilibration with 75 mg P/L in 0.01 *M* $CaCl_2$). Ammonium oxalate extractable Fe and Al were determined by the method of McKeague *et al*. (1971). In addition, P sorption isotherms were developed for all 40 soil samples by equilibrating soils overnight with solutions (0.01 *M* $CaCl_2$) containing varying amounts of P.

Infrared calibrations were developed using an Alpha R diffuse reflectance spectrometer (Bruker Optics - FTIR), with a spectral range of 375-7500/cm.

Results and Discussion

The range (and mean) for the PRF values for the Truog, Mehlich III and Resin extractants was 2.26-22.52 (5.84), 1.89-27.17 (7.13) and 4.39-39.68 (11.31), respectively. Should no sorption of any kind occur, this factor would theoretically be 1.5 kg P/ha per unit soil test.

Linear correlations between the PRF values and soil parameters are shown in Table 1. PRFs for the different extractants were highly correlated, and were also strongly correlated with other indices of P sorption (PDI, PSI and isotherm slope). Furthermore, strong relationships existed between PRFs and ammonium oxalate extractable aluminium and iron. Ammonium oxalate Al has been widely reported to be a reliable indicator of P fixation in soils, irrespective of their chemical and mineralogical properties (Singh and Gilkes, 1991; Bainbridge *et al*., 1995). PRF values were also strongly related to soil carbon content and volume weight. The stronger relationships between PRFs and volume weight relative to clay percentage contrasts somewhat with the findings of Johnston *et al*., (1987). These workers found clay percentage to be more strongly correlated with PRF values than volume weight for soils from mainly the interior of KwaZulu-Natal.

With laboratory incubations being time consuming and laborious, the use of MIR to predict PRF values would be of great value in routine soil testing. Encouragingly, fairly robust calibrations were developed for all three extractants. The Truog and Resin calibrations are shown in Figure 1.

Table 1. Linear correlation co-efficients relating Truog, Mehlich III and Resin PRFs with various soil properties (n=40).

	Vol. weight	Carbon	Clay	Oxal-Al	Oxal-Fe	PDI	PSI	Slope 0.2	Truog PRF	Mehlich III PRF	Resin PRF
Vol. weight	1.00										
Carbon	-0.86**	1.00									
Clay	-0.51**	0.26n.s	1.00								
Oxal-Al	-0.76**	0.92**	0.13n.s	1.00							
Oxal-Fe	-0.76**	0.71**	0.64**	0.72**	1.00						
PDI	0.80**	-0.65**	-0.69**	-0.62**	-0.75**	1.00					
PSI	-0.68**	0.87**	0.14n.s	0.95**	0.69**	-0.56**	1.00				
Slope 0.2	-0.78**	0.89**	0.27n.s	0.95**	0.70**	-0.72**	0.90**	1.00			
Truog PRF	-0.78**	0.82**	0.31*	0.86**	0.81**	-0.66**	0.78**	0.79**	1.00		
Mehlich III PRF	-0.69**	0.67**	0.63**	0.69**	0.93**	-0.70**	0.71**	0.66**	0.79**	1.00	
Resin PRF	-0.78**	0.87**	0.22n.s	0.92**	0.75**	-0.65**	0.87**	0.87**	0.89**	0.75**	1.00

**significant at $p = 0.01$; *significant at $p = 0.05$; n.s. – not significant

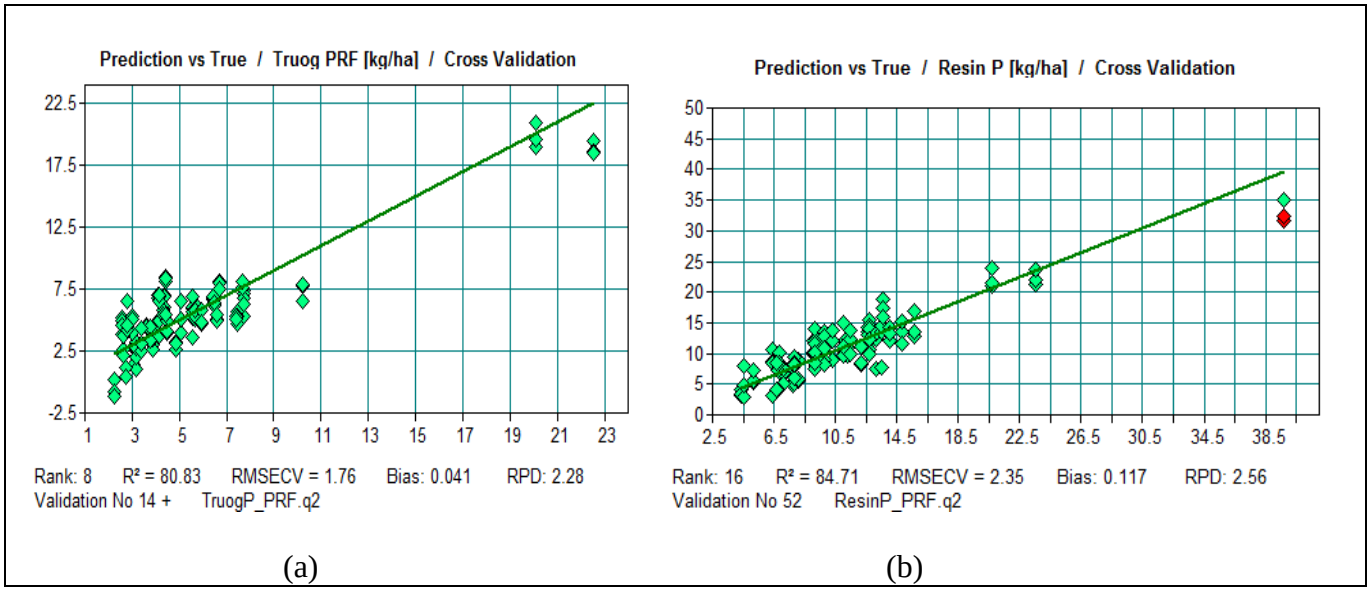

Figure 1. Mid-infrared cross-validations for (a) Truog PRF and (b) Resin PRF (n=40).

REFERENCES

Bache BW and Williams EG (1971). A phosphate sorption index for soils. *J Soil Sci* 22: 281-301.

Bainbridge SH, Miles N and Praan R (1995). Phosphorus sorption in Natal soils. *S Afr J Plant Soil* 12: 59-64.

Johnston MA, Farani MPW and Lawrence JY (1987). Estimation of soil texture from the sample density. Commun. Soil Sci. Plant Anl. 18: 1173 -1180.

Johnston MA, Miles N and Thibaud GR (1991). Quantity of phosphorus fertiliser required to raise the soil test value. *S Afr J Plant Soil* 8(1): 17-21.

McKeague JA, Brydon JE and Miles N (1971). Differentiation of forms of extractable iron and aluminium in soils. *Soil Sci Soc Am Proc* 35: 33-38.

Mehlich A (1984). Mehlich no.3 extractant: A modification of Mehlich no.2 extractant. *Commun Soil Sci Plant Anal* 15: 1409-1416.

Reeve NG and Sumner ME (1970). Effects of aluminium toxicity and phosphorus fixation on crop growth on Oxisols in Natal. *Soil Sci Soc Am Proc* 34: 263-267.

Singh B and Gilkes RJ (1991). Phosphorus sorption in relation to soil properties for the major soil types of south-western Australia. *Aust J Soil Res* 29: 603-618.

Warren GP (1994). Influence of soil properties on the response to phosphorus in some tropical soils: I. Initial response to fertilizer. *European J Soil Sci* 45: 337-344.