SHORT NON-REFEREED PAPER

PREDICTION OF PHOSPHORUS AVAILABILITY AND FIXATION IN SOILS OF THE SOUTHERN AFRICAN SUGAR INDUSTRY

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Abstract

Variations in soil properties across southern African sugar industries present particular challenges in terms of managing and estimating phosphorus (P) supplies to the crop. The Fertiliser Advisory Service (FAS) has traditionally made use of the Truog test for the estimation of plant available P supplies in soils, while P immobilisation (fixation) is determined by measuring the amount of added P desorbed by the Bray II solution. Concerns regarding the reliability of these acidic tests on higher pH soils led to alternate tests being evaluated. Phosphorus extracted with anion resin membrane strips was found to be closely related (r^2=0.96) to Truog-extractable P in soils with pH ($CaCl_2$) ≤5.0. However, at pH values of >5.0, the two tests were poorly related (r^2=0.38). This finding points to the Truog extraction being unreliable on higher pH soils due probably to the solubilisation of plant-unavailable calcium phosphates. Several P immobilisation indices were related to P sorption isotherm slopes for soils varying widely in texture and chemical properties. Ammonium oxalate extractable Al was found to be the best predictor of isotherm slope (r^2=0.96), while the Bache and Williams P sorption index also performed well (r^2=0.91). The Bray II-based index was not well related to isotherm slope (r^2=-0.63). Encouragingly, infrared spectroscopy was found to provide useful predictions of oxalate Al (r^2=0.91) and the Bache and Williams index (r^2=0.78), suggesting a role for MIR in predicting P immobilisation in the routine analysis of grower samples.

Keywords: phosphorus soil tests, resin P, Truog P, phosphorus sorption, mid-infrared spectroscopy

Introduction

Managing 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 P requirements. Worldwide, there are eight or more P tests in common use, with each of these tests having been designed for more or less specific soil conditions. The Fertiliser Advisory Service (FAS) at the South African Sugarcane Research Institute (SASRI) has long used the Truog (dilute sulphuric acid) test. Although apparently reliable on acid soils, the Truog test has been reported to over-estimate soil P availability (under-estimate fertiliser P requirements) on the neutral and alkaline soils typical of the northern irrigated areas (Meyer and Wood, 1989). Evidence of this has included leaf analyses reflecting P deficiencies on soils with very high Truog P test levels.

Phosphorus immobilisation (fixation), the process by which soluble P levels are reduced through reactions with soil components, is related to soil texture and chemical and mineralogical properties. The wide variations in these properties in the soils of southern Africa imply massive differences in P fixation: in laboratory studies on Natal soils, Bainbridge *et al.* (1995) found that the amount of P required to support an equilibrium soil P concentration of 0.2 mg P/L ranged from 5 mg P/kg soil to 1174 mg P/kg soil. FAS makes use of a Phosphorus Desorption Index (PDI) based on Bray II extractable P to estimate the magnitude of P fixation (Reeve and Sumner, 1970; Meyer and Dicks, 1979).

Concerns regarding the reliability of the acid P tests currently used in FAS led to the research reported in this paper. Objectives included, firstly, to compare the amounts of P extracted with the Truog and anionic resin membrane tests, and secondly, to evaluate several P fixation tests.

Materials and Methods

Investigations were carried out on 153 topsoil (0-200 mm) samples, 128 of which were from sugarcane fields in South Africa, 11 from sugarcane fields on the Dwangwa Estate in Malawi, and 14 were from virgin sites adjacent to sugarcane fields in South Africa. These soils ranged in clay content from 5 to 70%, in organic carbon from 0.42 to 9.72% and in pH ($CaCl_2$) from 3.47 to 7.45.

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 (Ionics AR103QDP) strips, 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. Truog P was 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) phosphorus desorption index (PDI) (overnight equilibration with a 200 mg/L P solution), and the Bache and Williams (1971) phosphorus sorption index (PSI) (18 h equilibration with 75 mg/L in 0.01 *M* $CaCl_2$). Ammonium oxalate extractable Fe and Al were determined by the method of McKeague *et al*. (1971). Phosphorus sorption isotherms were developed for a subset of 25 of the soils 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

Truog and resin P were poorly related (Figure 1a; r^2=0.29). The relationship between pH($CaCl_2$) and Truog-resin values (Figure 1b) indicates that the bulk of the deviation between the two tests occurred in samples with pH values of >5.0. Thus an excellent correlation existed between the two methods for soils with pH ≤5.0 (r^2=0.96), while for higher pH soils the relationship was poor (r^2=0.38). The tendency for acidic extractants to give inflated P values on high pH soils due to the dissolution of sparingly-soluble Ca-phosphates is well-documented, and the resin method has proved more reliable in estimating available P in soils differing widely in chemical properties (Leal *et al*., 1994; Nuernberg *et al*., 1998).

Ammonium oxalate extractable Al is 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). The Bache and Williams PSI was closely related to oxalate Al (r^2=0.87), while the PDI relationship with oxalate Al was poorer (r^2=0.33). For the subset of 25 samples for which sorption isotherms were developed, PSI and oxalate Al were more strongly related to isotherm slope than PDI (Table 1).

For the whole sample set of soils (n=153), fairly robust calibrations using infrared spectroscopy were developed for oxalate Al (r^2=0.91) and PSI (r^2=0.78). Furthermore, for the sorption isotherm subset, prediction of isotherm slope yielded r^2=0.78, suggesting that infrared spectroscopy offers a useful means of predicting P fixation in a routine, high throughput laboratory.

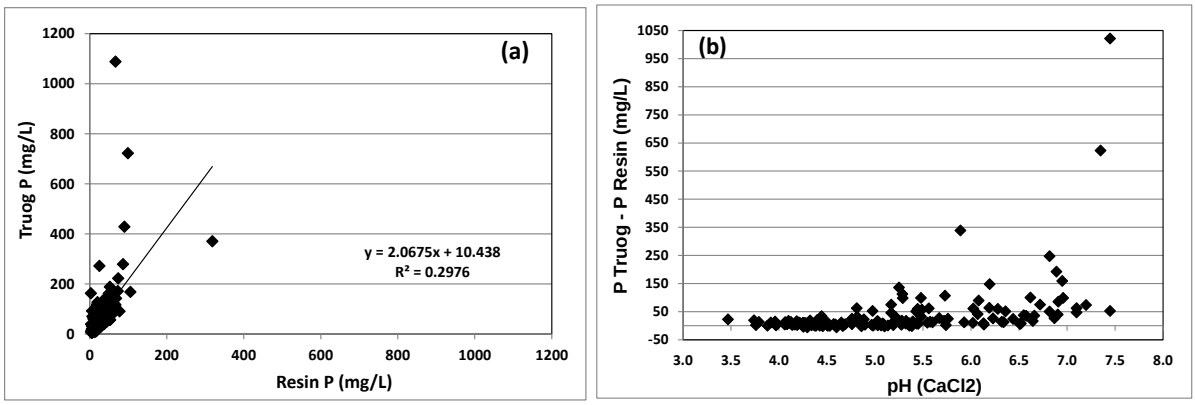

Figure 1. Relationships between (a) resin P and Truog P, and (b) between pH (CaCl2) and Troug minus resin (n=153).

Table 1. Linear correlation co-efficients for P sorption parameters (n=25).

	Oxal-Al	Oxal-Fe	Isotherm slope at 0.2 mg/L	P sorbed at 0.2 mg/L	PSI	PDI	Clay
Oxal-Al	–						
Oxal-Fe	0.866	–					
Isotherm slope at 0.2 mg/L	0.959	0.820	–				
P sorbed at 0.2 mg/L	0.870	0.769	0.861	–			
PSI	0.949	0.824	0.907	0.912	–		
PDI	-0.603	-0.661	-0.630	-0.592	-0.543	–	
Clay	0.076	0.376	0.157	0.146	0.066	-0.447	–

Conclusions

In terms of the most appropriate soil test for estimating plant-available soil P reserves, data presented here indicate that the Truog test frequently gives exaggeratedly high readings in soils with a pH ($CaCl_2$) of >5.0. The resin method, on the other hand, appears to be little affected by soil pH, and is thus a far more reliable alternative for predicting crop P requirements.

Oxalate Al and the PSI index are more reliable than the currently-used PDI index for predicting P fixation. Encouragingly, rapid and reasonably reliable prediction of the former parameters is possible using infrared spectroscopy.

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