EVALUATION OF FOUR SOIL-PHOSPHATE EXTRACTANTS AND PHOSPHORUS FIXATION IN SOILS FROM SWAZILAND SUGARCANE AREAS

By [1]P. C. HENRY, [2]G. SHONGWE and [2]V. BHEMBE

[1]*Inyoni Yami Swaziland Irrigation Scheme, Swaziland*
[2]*University of Swaziland*

Abstract

Four phosphate extraction procedures (Truog, Bray 1 and 2 and Ambic) and phosphorus (P) fixation were studied in a range of soils from the Swaziland and South African sugar industries. The results of a greenhouse experiment using maize as a test crop showed that the extractant best suited to Swaziland and South African soils was 0,02 N H_2SO_4 (Truog method) which is used by the Fertiliser Advisory Service (FAS) of the South African Sugar Association Experiment Station. The efficiency of the Truog extractant, however, differed between soils of the two countries. On average, one unit of Truog-P was more available in South African than in Swaziland soils, implying that when Truog-P analysis is interpreted, thresholds might have to be upgraded for Swaziland. The results of a laboratory investigation showed that, with the exception of two soils from the Natal Midlands, the range of values for P-fixation indices was similar for both South African and Swaziland soils. Although the soil constituents governing P-fixation differed between soils of the two countries, the relationship between the theoretical P requirement of the soil and P fixation indices for Swaziland soils was similar to that for South African soils. This suggests that the FAS procedure for determining P requirement is adequate for Swaziland.

Introduction

The diagnostic and recommendation system for phosphorus (P) nutrition of sugarcane used by growers in Swaziland is that developed by the Fertiliser Advisory Services (FAS) of the South African Sugar Association Experiment Station for non-Midlands soils. A detailed description of the system was given by Wood and Meyer (1989). Briefly, fertiliser rates depend on the status of soil-P measured by the Truog extractant (Truog, 1930) as modified by Du Toit *et al.* (1962) and range from 0 to 80 kg P/ha. Threshold values of 31 ppm and 11 ppm in terms of Truog-P are used to diagnose P deficiencies in plant and ratoon cane respectively. The work of Du Toit *et al.* (1962) in regard to the Truog extractant, as well as the response of sugarcane to fertiliser measured in trials reviewed by Du Toit (1957), form the basis of the FAS system. None of these trials, however, were conducted in the lowveld of Swaziland.

The performance of soil-P extractants as measured against plant uptake of P, their calibration and the response of crops to P fertiliser are often region-specific. Most recent evidence of this can be found in the work of Holford (1983), Holford and Cullis (1985) and Holford and Crocker (1988). Hence, extrapolating experimental results derived from one area to a different area, although expedient, contains an element of risk. Important differences in climate, management and soils, including their mineralogy, pH and base saturation levels, exist between the lowveld of Swaziland and Natal. These differences, the paucity of experimental work on P in Swaziland, and the occurrence of apparently strongly P-fixing soils in Swaziland, suggested that an adjustment of FAS P recommendations may be necessary.

Extractants are useful only if the quantities of P extracted relate to plant uptake across the range of soils characterising the area which is to be served. Different extractants often give different relationships between P extracted and P uptake by plants (Holford and Cullis, 1985). For a given extractant the relationship is also known to change from one area to another as soil types change (Holford, 1983). The coefficient of correlation of the relationship is a convenient means of comparing the performance (also termed efficacy by Holford) of different extractants.

The aim of this investigation, using regression analysis, was to test whether differences in the efficacy of P extractants and P-fixation existed between soils from the Swaziland and Natal sugarbelts. This was done to determine whether adjustments to the present system of FAS recommendations for P were warranted.

Procedure

Soils

Fifteen soils representative of the Swaziland lowveld and 13 soils of the Natal Midlands and Zululand were selected for this study. The soils originated from both virgin and cultivated lands and were classified according to the South African and Swaziland systems of soil classification (MacVicar *et al.*, 1977; Murdoch, 1972). Soil samples were collected from the 0-150 or 0-300 mm soil layers. The samples were air dried, passed through a 2 mm sieve and submitted for chemical analysis. Details of soil classification and some properties of the soils are summarised in Table 1.

Phosphate extraction

Phosphate in each soil was extracted by the Truog method following the procedure used by FAS and described by Du Toit *et al.* (1962). Subsamples of the soils were submitted for phosphate extraction using the Bray-1 and Bray-2 (Bray and Kurtz, 1945) and Ambic (van der Merwe *et al.*, 1984) methods. Procedures followed in these extractions conformed to those outlined in the Handbook of Standard Soil Testing Methods (Anon, 1990).

Greenhouse experiment

Duplicate pre-weighed pots were filled with soil to a volume of 2,5 l and arranged in a complete randomized block design. Before potting, potassium as muriate of potash (KCl) at rates specific to each soil was mixed with the soil to ensure that the potassium requirement of the test plants would be met. No P fertiliser was added and soil-P was the only source of P available to the plants during the experiment. Maize (cultivar TX 379) was used as the test plant and 12 seeds

Table 1

Some properties of the soils selected

Site	Depth (cm)	Soil[1]	Origin	Clay %	OM[2]	CBD-Fe[3]	CBD-Al[3]	CBD-Mn[3]	CEC[4]	TCEC	pHw	Truog	Bray-1	Bray-2	Ambic	Exchangeable cations			
				%					meq/100 g soil	meq/100 g clay		P ppm				K	Ca	Mg	Na
																ppm			
VS 7/2	0–15	R	IYSIS	36	2,58	1,39	0,13	0,032	31,81	88,36	7,65	6	9	9	4	156	4520	960	140
N4 Veld/2	0–15	S	SIM	39	2,27	3,07	0,24	0,059	11,45	29,36	6,00	4	6	4	3	517	1108	500	49
304/3-2	0–15	C	MHL	31	2,58	2,36	0,20	0,058	10,96	34,79	6,20	6	6	6	3	115	1347	400	70
332/2-3	0–15	E	Mhl	14	0,83	0,86	0,097	0,026	4,27	30,50	6,35	8	9	21	8	67	500	126	57
432/1-2	0–15	T	Mhl	32	2,06	2,37	0,28	0,062	8,57	26,78	5,95	5	6	5	4	113	895	400	63
Cotton V/2	0–15	C	Ubo	37	2,99	3,38	0,11	0,080	26,39	71,32	6,25	105	30	89	11	259	3500	910	81
SE4/3	0–15	D	IYSIS	25	2,27	1,66	0,22	0,037	6,29	25,16	5,85	7	5	3	3	274	571	283	40
Mbila 2/3	0–30	V	Ubo	54	2,70	4,77	0,29	0,095	23,59	43,68	7,07	6	6	6	3	302	2730	990	166
Ha 13	0–15	J	IYSIS	14	2,10	0,32	0,060	0,004	2,94	21,00	5,80	2	4	2	3	131	189	118	50
Citrus F1	0–30	V	Ubo	61	2,20	2,98	0,092	0,093	57,49	94,24	7,70	27	7	14	4	182	8320	1460	656
PK1	0–15	R	Mhl	46	3,50	4,75	0,18	0,10	23,24	50,52	5,80	8	7	7	3	214	2320	1240	59
H 11	0–15	H	IYSIS	22	2,90	0,61	0,095	0,031	12,65	57,50	7,00	10	9	9	5	391	1493	450	52
418	0–15	T	Mhl	46	3,50	2,41	0,20	0,066	22,37	48,63	6,20	12	7	8	3	260	2540	980	100
P1	0–15	R	Mhl	50	3,60	4,56	0,17	0,090	25,16	50,32	6,85	4	6	4	3	193	2830	1190	68
V Citrus/2	0–15	J	Ubo	61	3,70	2,93	0,14	0,10	47,22	78,56	7,55	21	9	16	3	366	6220	1380	870
100	0–15	Fw	Mtuba	10	1,23	1,29	0,16	0,083	4,62	46,20	6,35	6	5	6	4	51	646	105	42
101	0–15	Hu	Mtuba	12	0,41	1,38	0,24	0,082	2,22	18,50	6,10	3	4	2	3	43	223	88	14
103	0–15	Mg	Mtuba	54	3,81	8,48	0,80	0,10	12,64	23,41	5,80	4	5	4	3	139	1261	640	44
104	0–15	Sd	Red Hill	58	3,40	7,53	0,44	0,14	14,24	24,55	6,20	3	4	3	3	485	1398	660	71
105	0–15	Mg	Red Hill	47	4,43	4,71	0,61	0,089	17,47	37,17	6,25	3	4	3	3	345	1800	850	71
106	0–15	Sd	Dalton	71	4,33	8,08	0,92	0,027	7,45	10,49	5,75	2	5	4	2	52	696	400	26
108	0–15	Hu	N-Hanover	44	2,99	4,22	0,46	0,028	6,69	15,20	5,70	3	6	5	3	143	632	320	21
109	0–15	Hu	Wartburg	12	1,03	1,03	0,15	0,048	2,00	16,00	5,80	3	7	6	3	84	137	64	13
110	0–15	Ia	Wartburg	57	4,02	4,21	0,51	0,009	4,23	7,36	5,35	2	5	4	5	109	367	97	23
112	0–15	Gs	Dalton	12	1,13	0,82	0,10	0,024	2,11	17,58	5,50	3	6	4	4	66	156	83	16
302	0–30	Hu	Mtuba	47	2,74	6,90	0,46	0,12	8,81	18,74	5,40	3	5	4	3	148	1001	360	28
307	0–30	Cl	Dalton	15	1,23	0,50	0,078	0,022	2,14	14,27	5,50	6	9	8	5	77	204	60	5
311	0–30	We	Dalton	21	1,13	0,92	0,17	0,021	2,53	12,03	5,25	4	6	4	5	19	231	57	9

1) The first 15 soils were classified according to the Swaziland soil classification system (Murdoch, 1972), the last 13 soils were classified according to the Binomial soil classification system (MacVicar *et al.*, 1977)
2) By Walkley and Black procedure (1934)
3) By the method of Mehra and Jackson (1960)
4) In NH_4AOC at pH 7,5.

per pot were planted on 20 October 1991. Nitrogen as ammonium nitrate (NH_4NO_3) at a standard rate of 50 mg N/kg soil was top-dressed, and the soils were brought to field capacity with distilled water and thereafter were watered as required. The leachate was returned to the soil at each irrigation event. One week after emergence plants were thinned to three per pot. Forty-two days after sowing, the vegetative parts of the plants were harvested, dried, weighed, and after grinding were digested in concentrated sulphuric acid (H_2SO_4) and analysed for P.

Assessment of phosphorus fixation capacity

Two indices of the capacity of the soils to fix P were determined. These were the P desorption index (PDI) as determined by the procedure of Reeve and Sumner (1970) and a buffer power index (BPI) as measured from the slope of P adsorption isotherms (Bache and Williams, 1971). BPI is a more formal measure of P fixation than PDI. Meyer (1974), studying P-fixation in Natal Midlands soils, found PDI to agree with the P isotherm approach of assessing P-fixation. Being more suited to routine determination than BPI, PDI has since been used by the FAS as a measure of P-fixation to supplement Truog-P extractions when recommending P fertiliser for soils of the Natal Midlands. There was no evidence however that the relationship between PDI and P isotherms found by Meyer (1974) in Midlands soils held for Swaziland soils. This needed to be tested and both indices were therefore determined.

The method used in constructing the isotherms was similar to that used by Meyer (1974). The period of equilibration between soil and solution was 24 h and the temperature during equilibration was 20°C ± 1. Final solution P concentrations ranged between 0,025 mg P/l and 2 mg P/l. P sorbed was calculated by the difference between initial concentration of P added and final concentration of P in the supernatant expressed as mass of P fixed per unit mass of soil (mg P/kg). Isotherms were constructed by plotting P sorbed at each addition versus concentration of P in solution (Figure 1). The isotherms were described mathematically. Of the several sorption models tested, the Freundlich equation (Russell and Prescott, 1916) was found best to fit the data. The Freundlich equation is expressed as follows:

$$Y = Af\, x^{Bf} \qquad (1)$$

where Y and X are P sorbed (mg P/kg soil) and solution P (mg/l) respectively and Af, Bf are sorption coefficients. The slope of the Freundlich isotherm is given by the first derivative of equation (1):

$$dY/dx = Af\, Bf\, x^{Bf-1} \qquad (2)$$

As isotherms are curvilinear, the slope changes with the concentration of P in solution as indicated by equation (2). Hence, for comparative purposes BPI was taken as the measure of the isotherm slope at a standard concentration of 0,15 mg P/l, that is equation (2) was solved for dY/dx when X is equal to 0,15.

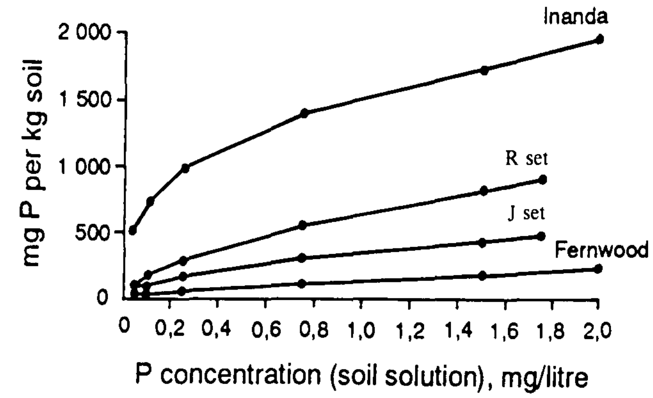

FIGURE 1 P adsorption isotherms of selected South African and Swaziland soils.

Soil P requirement

Beckwith (1965) first suggested that as an alternative to field trials, isotherms could be used to assess P fertiliser rates of different soils by the amount of P sorbed by soils at a solution P concentration known to be non-limiting to plant growth. The validity of this concept has since been demonstrated (Ozanne and Shaw, 1967; Peaslee and Fox, 1978; Azzaoui *et al.*, 1989) for soils from various parts of the world, including South Africa (Meyer, 1977). The optimum concentration of P in solution where growth is not limiting varies widely according to the crop (Fox, 1981). The choice of the non-limiting P concentration is important in making recommendations, as values higher than those needed for near maximum yield will lead to an over-estimation of the P requirement of the soils. In theoretical studies where the purpose, as in this investigation, was to obtain an index of the relative ranking of the P requirement of a range of soils, the concentration chosen does not matter. This was confirmed by Ozanne and Shaw (1967) who showed that the P requirement extrapolated at one concentration related to that obtained at another concentration. In this study the P requirement of the soils was interpolated from the isotherm at a concentration of 0,15 mg P/l.

Values of the Freundlich parameters, BPI, PDI and P requirement are presented in Table 2.

Results

Phosphate extraction

The range of values of extracted-P was wider in the Swaziland soils than in the South African soils (Table 1). One of the Swaziland soils (Cotton V/2) contained very high levels of plant extractable Truog-P, and Bray-1 and Bray-2-P levels. It was nevertheless included in this study because the Ambic-P value, although higher than in other soils, did not suggest an excessive P content.

Phosphorus uptake and soil-P extractants

During growth, purpling of the leaves became widespread in most soils, indicating P deficiency. The magnitude of the P deficiency and the limiting effect it had on growth can be gathered from the harvest data, by comparing yield of dry matter achieved in any one soil with that obtained in soil 'Cotton V/2' (Table 2). A similar trend was apparent for P uptake. The outstanding performance of soil 'Cotton V/2' more appropriately reflected the very high soil-P status, as measured by Truog, Bray-1 and Bray-2 extractants compared with the Ambic extractant, which was only moderately higher than that of the other soils. This was a first indication that, in the range of soils studied, the acidic extractants were better estimators of plant available P than the alkaline Ambic extractant.

Table 2

Sorption parameters and P requirement

Site	Soil	Freundlich Sorption Model $Y = Afx^{Bf}$				P requirement	
		Af	Bf	R^2	BPI	PDI	(kg P/ha)
VS 7/2	R	355	0,541	0,972	459	0,39	292
N4 Veld/2	S	418	0,603	0,982	536	0,46	324
304/3-2	C	416	0,599	0,996	533	0,37	292
332/2-3	E	197	0,555	0,984	254	0,66	162
432/1-2	T	417	0,572	0,999	537	0,35	322
Cotton V/2	C	338	0,627	0,997	430	0,48	238
SE 4/3	D	225	0,528	0,934	291	0,56	193
Mbila 2/3	V	583	0,543	0,977	754	0,27	472
Ha 13	J	177	0,603	0,972	227	0,68	121
Citrus F1	V	652	0,587	0,987	838	0,28	461
PK1	R	581	0,462	0,935	744	0,28	565
H 11	H	172	0,599	0,947	221	0,74	115
418	T	503	0,434	0,993	638	0,31	484
P1	R	576	0,505	0,974	744	0,28	495
V Citrus/2	J	409	0,650	0,980	516	0,37	286
100	Fw	133	0,796	0,955	156	0,80	61
101	Hu	175	0,700	0,990	216	0,77	110
103	Mg	622	0,423	0,990	786	0,18	598
104	Sd	463	0,409	0,980	582	0,26	475
105	Mg	576	0,460	0,931	734	0,30	562
106	Sd	1 237	0,329	0,970	1 454	0,20	1 498
108	Hu	570	0,525	0,975	737	0,40	479
109	Hu	189	0,599	0,982	424	0,74	133
110	Ia	1 533	0,332	0,968	1 809	0,17	1 885
112	Gs	166	0,744	0,971	200	0,80	97
302	Hu	455	0,462	0,975	570	0,41	414
307	Cl	183	0,692	0,994	227	0,73	115
311	We	236	0,616	0,982	301	0,69	175

Table 3

Yield of dry matter (YDM), % P and P uptake at harvest (values are means of two replicates)

Site	Soil	YDM (g/pot)	% P	P uptake (mg P/pot)
VS 7/2	R	3,20	0,12	4,00
N4 Veld/2	S	1,62	0,10	1,62
304/3-2	C	1,86	0,11	2,10
332/2-3	E	3,24	0,14	4,70
432/1-2	T	2,16	0,14	3,13
Cotton V/2	C	34,40	0,22	74,99
SE4/3	D	2,03	0,27	5,53
Mbila 2/3	V	3,43	0,32	11,16
Ha 13	J	1,24	0,16	2,05
Citrus F1	V	2,18	0,29	6,32
PK1	R	3,60	0,14	5,22
H 11	H	8,14	0,10	8,14
418	T	3,40	0,19	6,39
P1	R	1,93	0,16	3,14
V Citrus/2	J	5,86	0,18	10,56
100	Fw	4,48	0,22	9,76
101	Hu	1,46	0,15	2,24
103	Mg	2,77	0,22	6,19
104	Sd	1,28	0,15	1,96
105	Mg	1,41	0,085	1,20
106	Sd	1,30	0,13	1,69
108	Hu	2,77	0,25	6,88
109	Hu	3,85	0,17	6,54
110	Ia	0,82	0,19	1,54
112	Gs	3,83	0,11	4,33
302	Hu	1,88	0,13	2,44
307	Cl	2,68	0,22	5,84
311	We	2,67	0,11	3,02

The performance of the extractants in predicting plant available P was further tested by regressing P uptake against the amount of soil-P extracted by each extractant. Soil 'Cotton V/2', however, was excluded from the regression because P uptake associated with this soil was exceptional and its inclusion might therefore have biased the analysis.

The results of the regression analysis are summarised in Table 4. Truog-P was the only extractant relating significantly to P uptake in the Swaziland soils, while in the South African soils both Truog and Bray-2 P gave significant correlations. The values of r were low but concurred with those reported by Du Toit *et al.* (1962). The slopes of the equations of best fit for the Truog extractant were smaller in the Swaziland soils than in the South African soils. This implied that, for maize, the availability of one unit of Truog-P in Swaziland soils was on average lower than that in South African soils, but statistical treatment of the data showed that the difference in slope was not statistically significant (*Murdoch).

Phosphorus fixation

A range of sorption properties was represented by the selected soils. Figure 1 shows the extremes in sorption isotherms and they are also apparent from the PDI and BPI values in Table 2. There was a greater variation in P fixation in the South African soils because of the presence of two strongly P-fixing soils from the Natal Midlands (soils 106 and 110). Of interest is soil 103 which, although not from the Midlands, gave a PDI value similar to that of the two strongly P-fixing soils from the Midlands. The similarity in PDI values, however, was not reflected by the BPI values, which were much higher in the two Midlands soils than in soil 103. This suggests that a low PDI value in a non-Midlands soil does not indicate P-fixation of the same magnitude as that in the strongly P-fixing soils from the Midlands.

The relationship between BPI and PDI was further tested statistically and results are reported in Table 5. The high correlation existing between these two indices both in the Swaziland and South African soils (r = 0,821) confirmed that found by Meyer (1974) for Natal Midlands soils. This indicates that the PDI value can safely be extended beyond the Midlands area as a rapid index-measure of the P fixation capacity of soils. Equations (3) and (4) of Table 5, when solved for PDI, indicate that the relationships between BPI and PDI in Swaziland are similar to those for the moderately P-fixing soils from Zululand and the Midlands. The fact that the correlation coefficient for the regression of BPI on PDI was lower when it included the two strongly P-fixing soils from the Midlands, implies that the relationship between PDI and BPI in the strongly P-fixing soils from the Midlands is different from that found in the other soils. This confirms that strongly P-fixing values in non-Midlands soils do not necessarily mean P-fixation of the magnitude characteristic of strongly P-fixing soils from the Midlands.

Phosphorus fixation and soil properties

In order to identify the properties responsible for P-fixation, BPI was correlated against selected soil properties reported in Table 1. Citrate-bicarbonate-dithionite (CBD) extracts of aluminium (CBD-Al), iron (CBD-Fe) and manganese (CBD-Mn) characterise both the amorphous and crystalline Al, Fe and Mn sesquioxides (Boero and Schwertmann, 1989).

With the exception of clay, there were considerable differences in the effect of the various soil properties on P-fixation between South African and Swaziland soils. The r values for clay were similar for both countries while they differed for other properties (Table 6). Clay, CBD-Fe and Mn were the most important factors affecting P-fixation in Swaziland soils, while in South African soils they were clay, organic matter (OM) and CBD-Al. CBD-Fe and Mn, however, related to clay in Swaziland and CBD-Al related to both clay and OM in the South African soils. The affinity of P for sesquioxide minerals is well established (Ryden *et al.*, 1977; Barron *et al.*, 1988) and thus the close association between sesquioxide clay and OM suggests that a large proportion of the P sorbed by clay and OM is accounted for by the associated sesquioxides.

Table 4

Regression functions of best fit between P uptake (Y) and extracted P (x)

	Truog Equation	r	Bray-1 r	Bray-2 Equation	r	Ambic r
Swaziland	Y = 0,23x + 3,21	0,531*	0,428	NS	0,400	0,060
SA, all soils	Y = 1,46x − 0,92	0,690**	0,459	Y = 1,10x − 1,09	0,692**	0,340

* significant at (P = 0,05)
** significant at (P = 0,01)

Table 5

Regression functions of best fit between BPI and PDI

	Equation		r	Predicted BPI		
				PDI: 0,70	0,50	0,20
Swaziland	BPI = −1203 PDI + 1 034	(3)	−0,941**	192	432	793
SA except soils 106 and 110	BPI = −931 PDI + 963	(4)	−0,934**	311	497	777
SA, all soils	BPI = −1 578 PDI + 1 413	(5)	−0,821**	308	624	1 097

** significant at (P = 0,01)

* MG Murdoch, Head Biometry Department, SASEX

Table 6

Correlation matrix (r values) for the regression of BPI on soil properties

BPI	Clay	OM	CBD Extractable			CEC	TCEC	pHW
			Fe	Al	Mn			
Swaziland	0,866**	0,453	0,846**	0,408	0,848**	0,619**	0,363	0,291
SA except soils 106 and 110	0,900**	0,906**	0,816**	0,909**	0,410	0,758**	0,037	0,106
SA, all soils	0,814**	0,801**	0,581*	0,739**	−0,241	0,264	−0,400	−0,221

* significant at (P = 0,05)
** significant at (P = 0,01)

Table 7

Regression functions of best fit between P requirement (kg P/ha) and BPI

	Equation		r	Predicted P requirement		
				BPI: 250	500	750
Swaziland	Preq = 0,678 BPI-27	(6)	0,955**	142	312	508
SA except soils 106 and 110	Preq = 0,844 BPI-86	(7)	0,966**	125	336	547

** significant at (P = 0,01)

Phosphorus requirement

Phosphorus requirement in Swaziland soils ranged from 121 to 565 kg P/ha, while for South African soils it was between 61 and 1 885 kg P/ha (Table 2). In both Swaziland and South African soils, highly significant correlations were found between the P requirement and BPI. The quantitative relationship between P requirement and BPI was similar in both countries, which is evident when solving the equations of best fit (Table 7) for P requirement. Excluding the two strongly P-fixing soils from the Midlands, the predictions of P requirement for South African soils (equation 7) were roughly equal to those for Swaziland soils (equation 6).

Discussion

Phosphorus threshold values

None of the alternative P extractants widely used in South Africa were found to perform better than the Truog extractant currently used by FAS. Differences in the efficiency of the Truog extractant, however, were apparent between the two soil groups. Differences in pH, Ca saturation levels and affinity of sesquioxides for P between the two groups are likely to account for the differences in the efficiency of the Truog extractant, and further investigation is required to clarify this issue. If the lower efficiency of the Truog P extractant for Swaziland soils can be corroborated for sugarcane then the current FAS threshold values may be too low to diagnose a P deficiency and might need to be increased. A similar conclusion was reached by Meyer and Wood (1989) for the alkaline alluvial soils from Umfolozi and other areas of Natal subjected to past and recent flooding. Although cases of high soil-P/low leaf-P status on estates in Swaziland tend to support the need for adjustments, field trials will be necessary to confirm the results of the greenhouse experiment as well as to provide any data needed for possible revision of threshold values based on the Truog extractant.

Phosphorus corrective rates

The similarities in the relationship between P requirement and BPI in South African and Swaziland soils mean that, although the mechanism governing P fixation differs between the two countries, for soils with equivalent P status and similar BPI, the rate needed to correct P deficiency in Swaziland will be similar to that needed in South Africa. This suggests that generally the FAS P fertiliser recommendations are adequate for Swaziland soils.

For Natal soils the amount of phosphorus needed to raise Truog-P by one unit has been shown to relate closely to PDI (Johnston *et al.*, 1991). In view of the variability of P-fixation capacity found in this work, both in South African and Swaziland soils, the findings of Johnston *et al.* (1991) imply that the corrective rates currently recommended by FAS for non-Midlands soils may not always be adequate at the extremes of the PDI range. This has already been recognised (Meyer and Wood, 1989). These authors have reported that corrective rates for P in non-Midlands soils theoretically could be based on a dual consideration of the soil Truog-P status and PDI, as is the case for Midlands soils.

Conclusions

Using maize as the test plant, a preliminary investigation into soil-P tests and some of the P characteristics of soils of the Swaziland lowveld sugarcane growing areas, showed that the diagnostic and P fertiliser recommendation system used by the FAS was largely adequate for Swaziland.

Generally the results confirmed the adequacy of the Truog extractant for estimating plant available P in Swaziland soils. Although differences in efficiency of the Truog extractant for Swaziland and South African soils were apparent, there was insufficient evidence to justify a change in the threshold value for P. Both pot and field trials with sugarcane will be needed to corroborate the findings with maize.

PDI was found to be a good index of the P-fixing capacity of soils of the Swaziland lowveld. However, for the same PDI value the magnitude of P-fixation in Swaziland is expected to be much lower than that of the strongly P-fixing soils from the Natal Midlands, and no justification was found for using rates higher than those currently recommended by FAS for non-Midlands soils.

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