COST IMPLICATIONS AND GROWER PERCEPTIONS OF PHOSPHORUS FERTILISER RECOMMENDATIONS BASED ON SOIL TESTS NOT CALIBRATED FOR SUGARCANE

F BOTHA and J H MEYER

South African Sugar Association Experiment Station, P/Bag X02, Mount Edgecombe, 4300, South Africa

Abstract

Input costs for sugarcane production have escalated sharply over the past five years, especially fertiliser costs. It has become imperative for growers to manage fertiliser input costs by ensuring that they have an accurate nutrition management programme in place. The South African Sugar Association Experiment Station has, over many years, contributed hugely through their research and extension departments to developing standard methods of soil analysis and critical soil norms for making cost effective fertiliser recommendations for sugarcane. The leading role that the Fertiliser Advisory Service (FAS) has played in this regard is widely acknowledged, both locally and internationally. However, in recent years growers in the north have made increasing use of laboratories where the soil tests have not been calibrated for sugarcane. This has led to diverse fertiliser recommendations and to considerable confusion among growers, as the recommendations call for excess application of phosphorus (P) and potassium (K) fertilisers in particular. This is not in the best interests of growers, nor of the fertiliser and cane processing industries. The focus of this paper is to look at the implications of using P fertiliser recommendations that are based on different soil phosphate extraction procedures than those of FAS, and that are not calibrated for sugarcane production.

Keywords: sugarcane, fertiliser, phosphorus, soil analysis

Introduction

At present cane production in Mpumalanga is characterised by large inputs of nitrogen (N), phosphorus (P) and potassium (K) fertilisers, which with escalating price increases over the past three years, may amount to 25% of total production costs. Available evidence indicates that in parts of the Onderberg supplying cane to the Malelane and Komati mill, the average fertiliser cost per ton of cane is 30 to 40% higher than in other irrigated regions in the South African sugar industry. It is well known that over-application of fertiliser is not only wasteful, but can lead to a reduction in sucrose content and seriously affect profitability.

Some of the reasons for over-application include:

- The belief by some growers that extra fertiliser is an investment to capitalise on a good crop in seasons with favourable growing conditions.
- The perception that the region's yield plateau may be linked to a nutritional imbalance, especially a lack of P and K.
- The notion that current FAS recommendations are not sufficient for Mpumalanga conditions, especially where P and K are concerned.
- The use of laboratories other than FAS, where the soil test procedures have not been calibrated for sugarcane, frequently leading to excessive applications of P and K.

With escalating fertiliser costs and no indication of the yield plateau being broken, it has become imperative that fertiliser input costs are carefully managed, and that an accurate nutrition management programme based on soil tests calibrated for sugarcane be secured. This paper reports on a study that was undertaken to determine the cost and other implications of using P recommendations that have been based on laboratory soil phosphate extraction procedures not calibrated for sugarcane production.

Methods and procedures

The investigation was conducted in four phases:

- Determining the trend in yield productivity for the Malelane region since 1982, using Mill Group Board statistics.
- Establishing the range of average fertiliser costs for the main irrigated areas, using South African Cane Growers' Association cost survey statistics.
- Conducting a series of surveys on the P status of soil samples sent from the Mpumalanga region to the four major laboratories for analysis.
- In the first survey, five bulk samples, representative of the main soil parent materials in Mpumalanga, were taken. These were split into four sub-samples, and one sub-sample was sent to each of the four major laboratories for nutrient determination by the standard Truog method (labs 1 and 4), the Bray P1 method (lab 2) and the Ambic 1 method (lab 3). Although the latter two methods are widely used for other crops, they have not been calibrated for sugarcane, implying that no scientifically derived threshold values are available for South African conditions.
- In the second survey, available records of grower and miller-cum-planter soil analyses performed by the four laboratories were compared, and the impact on P fertiliser requirement determined.
- Comparing the overall trend in soil P availability in Mpumalanga with the other lowveld regions, using data captured from over 20 000 soil samples analysed by FAS since 1980. The computer program that was used is referred to as the 'Nutrient Information Retrieval System' (NIRS), which was developed specifically to capture and store soil and leaf analysis data, and to carry out surveys in which the frequency distribution of important soil and plant nutrients are categorised into various stages of sufficiency for different extension areas (Meyer *et al.*, 1989).

Results and discussion

Trend in yield productivity

The Malelane Mill Group Board yield and cane quality data for the 1981/82 to 2003/04 seasons is summarised in Appendix 1. While there is clear indication of an improvement in cane quality due to the combined effects of improved varieties and the use of chemical ripeners, the same cannot be said for average cane yields, which have declined and resulted in an overall sucrose yield plateau over the last 20 years (Figure 1). An important factor that has limited cane yields is the gradual expansion of the industry into areas with marginal soils that are susceptible to compaction, and drainage and salinity problems.

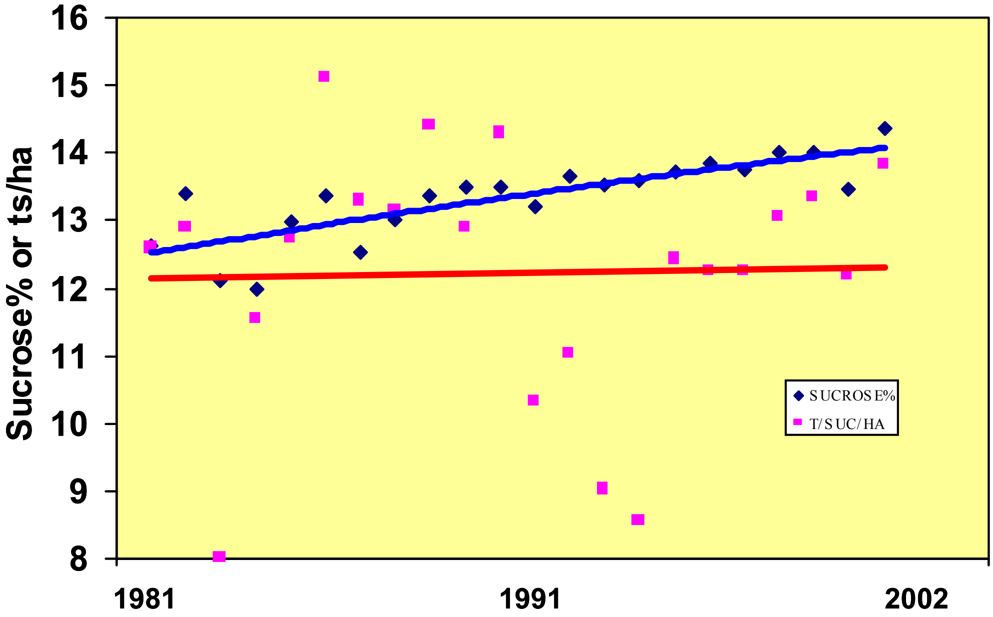

Figure 1. Trends in average annual sucrose % cane and sucrose yields from 1981 to 2002.

Comparative average fertiliser costs for the irrigated cane areas
Table 1 gives a comparison of average fertiliser costs per ton of cane produced, as well as per hectare for the three main production areas under irrigation (Anon, 2002). Overall, the data indicated that in 2002, fertiliser costs per hectare of cane produced were highest in Mpumalanga, being more than double the fertiliser costs in the Umfolozi region and 50% higher than those in the Pongola area. Where fertiliser costs were expressed on a per ton cane basis, Mpumalanga still had the highest costs, although the differences between the three regions were less. The results imply that, in general, Mpumalanga growers applied more fertiliser per unit area than the other irrigated regions, and derived very little advantage from extra sucrose % cane.

Table 1. Comparative fertiliser costs for the main irrigated cane areas from 1996/97 to 2000/01.

Area	1996/97		1997/98		1998/99		1999/00		2000/01		2001/02	
	R/ton	R/ha	R/ton	R/ha	R/ton	R/ha	R/ton	R/ha	R/ton	R/ha	R/ton	R/ha
Pongola	14.6	1119.7	13.4	1060.2	16.0	1176.1	13.7	1143.9	13.6	1103.4	17.1	1218.6
Umfolozi	9.7	797.0	12.2	1049.5	9.7	729.9	7.3	688.4	8.8	786.2	13.8	991.3
Mpumalanga	16.4	1324.2	14.6	1395.6	16.2	1452.7	14.0	1313.2	16.4	1677.2	21.2	1862.5

Main characteristics of soil extractants used by laboratories investigated
Various extractants have been tested across sugar industries to index plant available P in soil. It appears, however, that the modified Truog method has been the most widely used for advisory purposes in Hawaii, Mauritius, Brazil, the Philippines and Australia. The main features of the extractants that are the subject of this investigation, as used by FAS, a fertiliser company laboratory, a private laboratory and a government laboratory, are summarised in Table 2.

Table 2. Main characteristics of soil extractants used by four different laboratories.

Soil extractant	Truog P	Bray P1	Ambic P
Reagents	H_2SO_4	NH_4F/HCl	$NH_4HCO_3/(NH_4)_2$ EDTA
Reaction	Acid	Acid	Alkaline
Extract:Soil	50:1	10:1	10:1
Extraction time (min)	30	1	30
Main P forms	Ca>Al>Fe	Ca=Al>Fe	Ca=Al>Fe
TV Plant (ppm)	31	Not determined	Not determined
TV Ratoon (ppm)	11	Not determined	Not determined
Reference	Truog (1930)	Bray and Kurtz (1945)	van der Merwe *et al.* (1984)

The modified Truog single acid extractant is stronger than the Bray P1 combination of acids, and the AMBIC extractant has a strong alkaline reaction. While all three procedures are locally accredited by the Agricultural Laboratory Association of South Africa (AgriLASA), only the Truog extractant has been carefully calibrated for sugarcane in South Africa under a wide range of bioclimatic and soil conditions, by correlating soil analysis data with yield responses to P treatment in 31 exploratory 3Nx3Px3K factorial trials and 53 4Nx2Px3K regional fertiliser trials. Of the many methods that have been tested, including Bray P1 and a surrogate method of Ambic, the modified Truog extractant gave the best correlation between soil P levels and response to applied P fertiliser (du Toit *et al*., 1962).

The trial data indicated that the response to applied P for plant cane was inversely related to the level of plant available P prior to treatment, and that economic responses at soil P levels in excess of 30 ppm were extremely unlikely (Figure 2). A threshold value of 31 ppm was selected for the plant crop, and 11 ppm was selected for ratoons (du Toit *et al*., 1962).

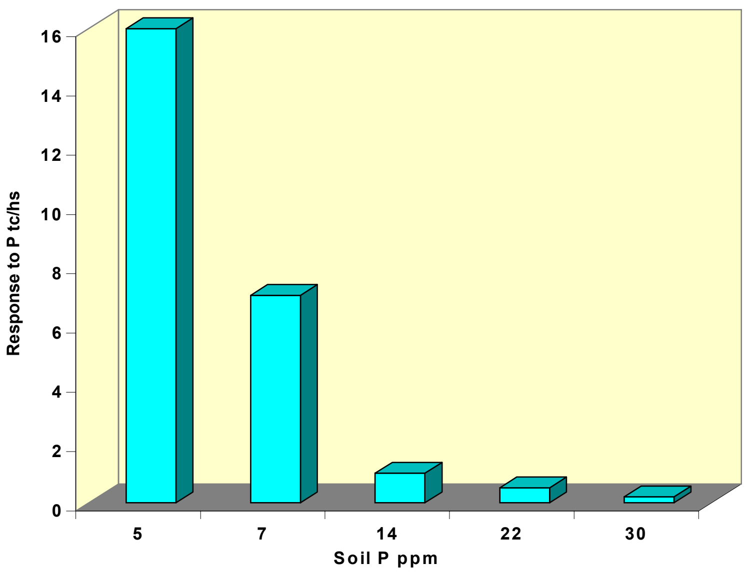

Figure 2. Relationship between responses to applied P and pre-treatment soil P levels (after du Toit *et al*., 1962).

In testing the reliability of these threshold values, Bishop (1967) concluded that responses to applied P would have been correctly predicted in 72% of instances and incorrectly in 16%, while predictions in the remaining 12% would have been of doubtful value. Subsequent trials conducted in Pongola have confirmed these threshold values (Meyer and Wood, 1989), while a recent study carried out on Swaziland soils, using a range of soil extractants, showed that the Truog soil extractant provided the best correlation with yield response to applied P fertiliser (Henry *et al*., 1993).

In practice, from an advisory viewpoint, the soil P level is made up to 90 kg/ha at crop establishment in accordance with the amounts of P extracted from the soil. Sufficient P fertiliser is normally applied in the furrow to meet the P requirements of at least the plant crop and the first ratoon. Subsequent ratoon cane requirements should be top-dressed as soon after harvest as possible.

Results of soil samples analysed by different laboratories

The results of the five bulk soil samples that were analysed by the four major laboratories in Mpumalanga using different P extractants are summarised in Table 3. In general, the results indicate that the Truog method can extract two-and-a-half times more P than the Bray P1 method, and about four times more P than the Ambic method. Despite the large differences in extraction efficiency between extractants, advisors who have used the Bray P1 and Ambic-derived results have wrongly relied on the Truog-derived threshold value of 31 ppm for interpreting their analyses.

As shown in Table 3, when a threshold value of 31 ppm was assumed, this has led to a false diagnosis of higher P deficiency than actually existed, particularly in ratoon cane. With the FAS Truog extractant, only one of the five samples analysed indicated a need for P, whereas interpretation of the Bray P1 and Ambic results showed that four of the five samples required additional P fertiliser.

Table 3. Comparison of soil P results for five bulk soil samples analysed by four different laboratories.

Soil sample	Site	Soil pH (water)	FAS: Truog P	Lab 2: Bray P1	Lab 3: Ambic	Lab 4: Truog
Granite	Malelane	7.04	24	10	4	21
Swazi Basic	Malelane	7.3	19	4	4	19
Granite	Nelspruit	6.3	115	50	48	88
Basalt	Komati	6.9	35	16	8	29
Ecca Shale	Komati	8.6	8	3	3	10
No. samples deficient		Plant	3*	4**	4**	4*
		Ratoon	1*	4**	4**	1*

*Threshold values of 31 ppm and 11 ppm for plant and ratoon cane respectively
**Threshold value of 31 ppm for plant and ratoon cane as adopted by some advisors

Similar findings were obtained for the samples from the miller-cum-planter estates that were analysed by the same three extractants (Table 4). However, this time, for plant cane advice, all 10 fields analysed by the Bray P1 and Ambic methods were deemed to require P, whereas only two fields qualified for extra P with the Truog method. Where the advice was for ratoon cane, according to the Truog criteria all the fields contained sufficient P, while according to the other criteria, 10 of the 11 fields required P. The survey of grower samples analysed by the same three extractants produced a similar outcome. Based on a field size of 10 ha, a P requirement of 40 kg P/ha and a unit cost of R15/ha, the cost of P for the 10 fields would have been R12 000 for the Truog and R60 000 for the Bray P1/AMBIC based criteria. Using the Truog method, a saving of R48 000 or R480/ha is therefore possible in plant cane. In ratoon cane the saving is potentially larger, amounting to R60 000 or R600/ha. In practice, had the correct threshold values for the Bray P1 and Ambic extractants been available (likely to be below 10 ppm), the interpretation of P requirement would have been more consistent with the diagnosis by the Truog method.

Table 4. Comparison of soil P results for 10 fields analysed by three different laboratories.

Field number	Truog (ppm)	Bray (ppm)	Ambic (ppm)
1	56	27	25
2	19	14	12
3	32	16	18
4	51	12	15
5	31	19	21
6	52	28	27
7	80	23	20
8	60	19	16
9	48	25	23
10	32	14	11
No. deficient: plant	2	10	10
No. deficient: ratoon	0	10	10

NIRS fertility trend assessment

It is clear from an assessment of the available data that the P status of the soils in the irrigated areas is among the highest in the industry (Figure 3). Since 1980, P levels have increased steadily, and in 2003 were about 50% higher than the industry average, and about four times higher than the threshold value of 11 ppm used for ratoon cane.

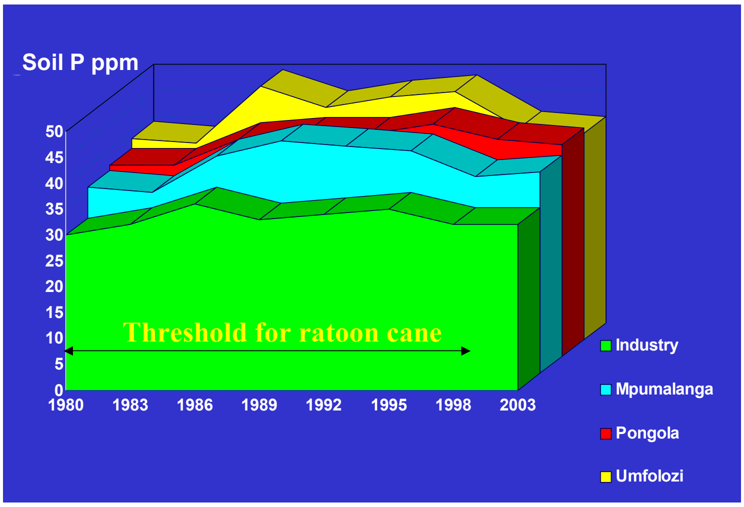

Figure 3. Trends in P status in the main Lowveld areas from 1980 and 2003.

Discussion

Phosphorus is required by sugarcane in amounts that are generally much lower than N or K, the average being about 20-25 kg P per hectare (Meyer and Wood 1989. There was a time when P fertiliser was cheaper than N or K, but this nutrient is currently nearly four times more expensive on a unit cost basis than both N and K. Despite this, the findings of this investigation indicate that soils in the Mpumalanga region are generously supplied with P, and that in many instances no additional P fertiliser is needed for ratoon cane. It seems likely that the current high fertiliser expenditure in the Mpumalanga region is being compounded by poor P fertiliser recommendations that are based on soil tests that have not been calibrated for the P requirement of sugarcane.

Although P reserves in soils tend to be slowly available, being held in the organic, inorganic or sorbed forms (Meyer, 1974), it is evident that the Bray P1 and Ambic extractants largely underestimate the true amount of plant available orthophosphate ($HPO_4^{=}$ or $H_2PO_4^{-}$) ions that are taken up by sugarcane. Depending on soil pH, P is often released from soils in an on-going manner, resulting in a slow but steady supply of plant available P. Tri-calcium phosphate which is often perceived to be a poorly available source of P, is the more important inorganic form of P found in neutral to slightly alkaline soils. In a glasshouse study with sugarcane, it was shown that this form of P for sugar cane, can potentially be 70% as effective as the more soluble calcium di-hydrogen phosphate, the main component of single superphosphate (du Toit *et al*., 1962). Other inorganic forms that supplied P but were less efficient, included aluminium phosphate (30% P), iron phosphate (15% P) and calcium tri-phosphate more commonly known as apatite (10% P) (Figure 4).

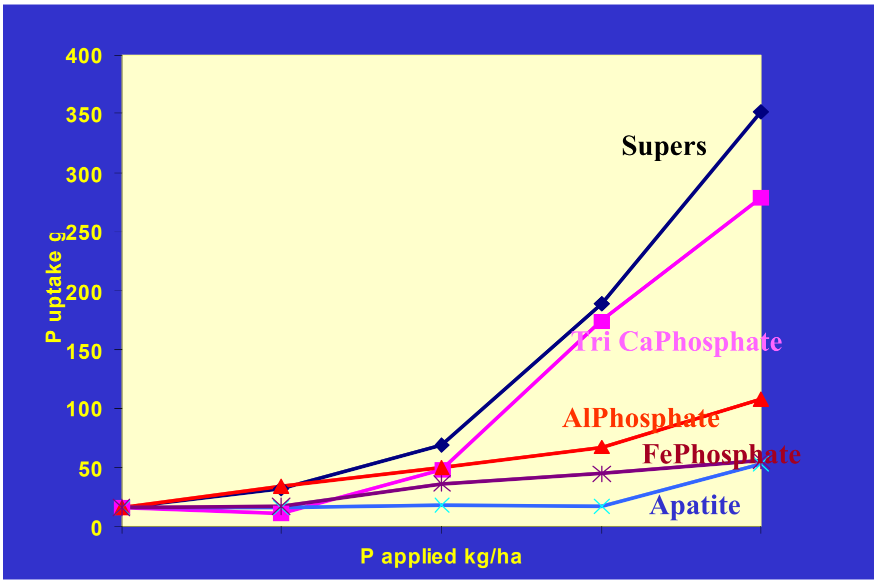

Figure 4. Relative uptake of P by cane from different P carriers (after du Toit *et al.*, 1962).

A follow-up assessment of the main inorganic forms of P extracted by various soil extractants showed that the Truog method removed a much higher proportion of the available tri-calcium phosphate form than the Bray P2 extractant, which was more in keeping with the measured P taken up from this inorganic form by sugarcane (Figure 5). It may be assumed that the weaker Bray P1 extractant will remove even less P from tri-calcium phosphate than the stronger Bray P2 extractant, which will explain the high incidence of low soil P values obtained in grower samples relative to the values obtained with the Truog method. The Ambic extractant likewise underestimates the amount of available tri-calcium phosphate form of P.

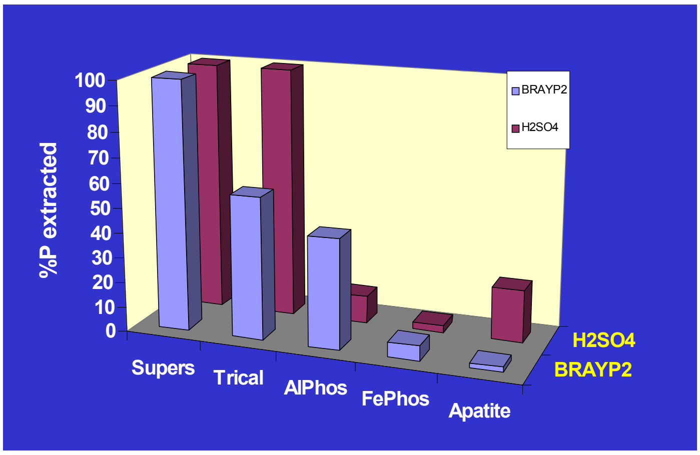

Figure 5. Relative amounts of inorganic P extracted by the Truog and Bray P extractants (after du Toit *et al.*, 1962).

Apart from incurring higher fertiliser costs, there is the concern that over-application of P fertiliser will lead to surface loss of particulate P to the environment and elevate the levels of P in fresh water bodies, which will lead to algal blooms and proliferation of water hyacinth (Kinsey, 1990). Concern has also been expressed that excessive use of P-based fertilisers will have a negative impact on uptake and utilisation of zinc, as reported by Trier and Bergmann, (1974), in crops such as flax and maize. Although there is field evidence of induced copper deficiency in sugarcane associated with use of broadcast super phosphate at 1.25 t/ha, there is no such evidence for zinc. The reported interactions between Cu, Zn and P could be associated with biomass dilution from the P response, and cations associated with P fertilisers might inhibit uptake of the trace elements, or P enhancing sorption of trace elements on soil particles (Loneragan *et al.*, 1979).

Conclusions

Based on the cost assessment and the relatively high P status of soils in the Mpumalanga region, it may be concluded that there has been a general over-use of P fertiliser, and that current FAS recommendations are sufficient for Mpumalanga conditions. Confusion regarding the correct amount of P that should be applied in this region has come about largely by some growers using laboratories with extraction methods that have not been calibrated for sugarcane. Applying the Truog-derived threshold value of 31 ppm to soil analysis data that is based on the Bray P1 or Ambic extractants will lead to underestimation of plant available P levels, and P fertiliser recommendations that cannot be justified on economic grounds through increased yield responses. Workshops have been organised locally with fertiliser companies, laboratories and consultants, and on a national level with the Fertiliser Society of South Africa and AgriLASA, to standardise the soil test procedure for P requirements in sugarcane. This initiative has been successful and all parties involved with soil analysis for sugarcane production have agreed in future to use the Truog method.

Standardising on the Truog method will lead to greater consistency in results, better interpretation of fertiliser advice and generally less P being applied, thereby reducing costs significantly. Above all, it is hoped that confidence in soil testing and fertiliser recommendations will be restored in the Onderberg. If standardisation is implemented, this region's fertiliser input costs will be more in line with those of the other regions. The potential saving is approximately R600 per ha for ratoon cane, which would generate a saving of R14 million per annum, based on the assumption that 60% of the region does not require P application to ratoon cane. The savings will be even more significant if soil samples sent to these laboratories from other regions are included. Given the present price squeeze facing growers and the industry, there can be little doubt that these savings will make a big difference to the financial viability of many growers.

REFERENCES

Anon (2002). Annual Grower Survey Report. South African Cane Growers' Association, Flanders Drive, Mount Edgecombe, 4300, South Africa.

Bishop,RT (1965). A measure of the reliability of predicting yield responses to applied P fertilizer. *Unpub paper S Afr Sug Ind Agron Ass.*

Bray RHI and Kurtz LT (1945). Determination of available forms of P in soils. *Soil Sci* 53: 39-45.

du Toit JL, Beater BE and Maud RR (1962*).* Available soil phosphate and yield responses in sugarcane. *Proc int Soc Sug Cane Technol* 11: 101-111.

Henry PC, Shongwe G and Bhembe VE (1993). Evaluation of four soil phospate extractants and P fixation in soils from Swaziland areas. *Proc S Afr Sug Technol Ass* 63: 60-66.

Kinsey DW (1990). Water quality and its effects on reef ecology. pp 192-196 In: D Yellowlees (Ed) *Land Use Patterns and Nutrient Loading of the Great Barrier Reef Region.* Sir George Fisher Centre for Tropical Marine Studies, James Cook University, Townsville, Queensland, Australia.

Loneragan, J. F, Grove, T. S., Robson, A. D. and Snowball, K. 1979. Phosphorus toxicity as a factor in zinc- phosphorus interactions in plants. *Soil Sci. Soc. Amer. Proc.*43: 966-972.

Meyer JH (1974). P fixation: A growth limiting factor in some soils of the South African sugar industry. *Proc int Soc Sug Cane Technol* 15: 586-600.

Meyer, JH and Wood, RA (1989). Factors affecting phosphorus nutrition and fertiliser use by sugarcane in South Africa. *Proc S Afr Sug Technol Ass* 63: 153-158.

Meyer JH, Wood RA and Harding RL (1989). Fertility trends in the South African sugar industry. *Proc S Afr Sug Technol Ass* 63: 159-163.

Trier K and Bergmann W (1974). Ergebnisse zur wechselseitigen Beeinflussung der Zink-und Phosphorsäureernährung von Mais (*Zea mays* L.) *Arch Acker-Plflanezenbau Bodenkd* 18: 65-75.

Truog, E (1930) The determination of readily available phosphorus in soil. *J.Am.Soc.Agron.22: 874-878.*

van der Merwe AJ, Johnson JC and Ras LSK (1984). A NH_4 $HCO_3/(NH_4)_2$ EDTA method for determining extractable P, K, Ca, Mg, Cu, Zn, Mn and Fe in soils. SIRI Information Bulletin B2/2, Department of Agriculture and Fisheries, South Africa.

APPENDIX 1

YIELD REPORT: MALELANE MILL GROUP BOARD

1981/82 to 2003/04 Seasons

Season	Hectares under cane	Total tons cane	Tons cane/ha	Sucrose % cane	Tons sucrose/ha	ERC % cane	Tons ERC/ha
1981/82	16 880	1 681 967	99.6	12.6	12.6	10.9	10.8
1982/83	17 559	1 691 224	96.3	13.4	12.9	11.4	11.0
1983/84	15 523	1 017 549	65.5	12.1	7.9	10.0	6.6
1984/85	16 724	1 609 648	96.3	12.0	11.5	10.0	9.6
1985/86	16 704	1 642 078	98.3	13.0	12.8	11.2	11.0
1986/87	16 151	1 817 710	112.5	13.4	15.0	11.6	13.0
1987/88	17 252	1 832 766	106.2	12.5	13.3	10.6	11.3
1988/89	16 760	1 691 701	100.9	13.0	13.1	11.2	11.3
1989/90	16 288	1 755 528	107.8	13.4	14.4	11.6	12.5
1990/91	17 487	1 867 346	106.8	13.5	14.4	11.7	12.4
1991/92	18 813	1 991 587	105.9	13.5	14.3	11.7	12.3
1992/93	17 615	1 374 860	78.0	13.2	10.3	11.0	8.6
1993/94	16 839	1 359 177	80.7	13.6	11.0	11.8	9.5
1994/95	13 324	889 981	66.8	13.5	9.0	11.5	7.7
1995/96	13 969	881 186	63.1	13.6	8.6	11.5	7.2
1996/97	14 336	1 298 698	90.6	13.7	12.4	11.9	10.8
1997/98	17 651	1 561 016	88.4	13.9	12.2	12.1	10.7
1998/99	17 513	1 558 511	89.0	13.8	12.2	11.9	10.6
1999/00	18 916	1 738 741	91.9	14.0	12.9	12.3	11.3
2000/01	20 148	1 916 799	95.1	14.0	13.3	12.2	11.6
2001/02	20 343	1 759 765	86.5	13.4	11.6	11.6	10.0
2002/03	19 741	1 852 369	93.8	14.4	13.5	12.6	11.8
2003/04	20 410	1 833 911	89.9	14.3	12.8	12.3	11.1