INTERACTION BETWEEN POLYMER COATED NITROGEN FERTILISERS AND RAINFALL ON VEGETATIVE GROWTH VERSUS RIPENING

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Abstract

Using maize as the indicator crop for recently tilled soils over seven successive seasons, urea prills coated with 0,5% polymer gave the greatest grain yield increases over commercial urea in seasons of below average rainfall (3,3 tons/ha versus 1,6 tons/ha in 1989-90). The ratios of grain to stover were also higher. In wet years, no differences were recorded. The concentrations of Ca and Mg in the leaves were also higher in the drier seasons and were strongly correlated with the increased grain yields (r = +0,8933 and +0,8922 respectively). In trials with ratoon cane on untilled soils, the polymer coated urea and LAN treatments (both at 0,5%) gave the expected higher ers % cane values (NS) than their commercial equivalents in seasons of normal and high rainfall, but not in a drought season. The variable responses in tons cane/ha induced by the coated fertilisers, together with the chemical compositions of leaf and soil samples, suggest that thinner polymer coatings are required for ratoon cane.

Introduction

Trials with maize and sugarcane (Bishop, 1993) showed that prills of urea or LAN coated with 0,5% of a styrene-octyl acrylic polymer initiated substantially more plant available N and more grain in recently tilled soils and higher ers % cane and fibre % cane values in ratoon crops than did equivalent uncoated commercial fertilisers. Coated LAN gave more tons cane and more tons ers/ha than commercial LAN. Season to season consistency in the effectiveness of treatments needed to be assessed. Seven successive seasons of maize trials and three seasons of ratoon cane were investigated. Of the two coatings tested previously (Bishop, 1993) with ratoon cane the thicker one of 0,5% polymer was selected as it encouraged both vegetative growth (tons cane/ha) and earlier maturing (higher ers % and fibre % cane) with LAN at both 80 and 120 kg N/ha, while at the 0,01% polymer level only increased vegetative growth was induced at 80 kg N/ha.

Procedure

Experiments 1 to 7 - Maize

The experiment site was located on an Avalon series soil at Dundee, Northern Natal. Each year, from 1987 to 1993, different N treatments were applied at different rates of N to newly randomised plots. The design was a randomised block with either four or five replications and the plant used was maize. (Bishop, 1977; 1992; 1993). For the purpose of this paper only the treatments receiving commercial urea prills and urea prills coated with approximately 0,5% of styrene octyl acrylic polymer at approximately 40 kg N/ha were compared (Table 1). The equivalent of 95 kg P/ha and 50 kg K/ha were broadcast over the test area and incorporated before planting. Leaf samples were taken at the tasselling stage (11 weeks after planting), and analysed for N, Ca, and Mg (Table 1). At harvest the mass of grain was recorded and the total rainfall from October to March (inclusive) was calculated and expressed as a percentage of the 26 year mean (Table 1).

Experiments 8, 9 and 10 - Sugarcane

Polymer coated urea and LAN (both at 0,5%) treatments were tested on the first ratoon (Experiment 8) and second ratoon (Experiment 9) crop of NCo376 sugarcane on a Longlands/ Westleigh soil at La Mercy Experiment Farm and also on a first ratoon crop of N19 (Experiment 10) on a Middle-Lower Ecca shale at Grandpré Sugar Estate, Gingindlovu. The experimental design for Experiments 8 and 9 was a Latin square with six replications and for the Experiment 10 it was a randomised block with four replications. The different N treatments and the P and K requirements were top-dressed as per Fertiliser Advisory Service recommendations. Third leaf N, P, K, Ca and Mg values were determined from samples taken when the cane was four, six and seven months in Experiment 8, three months in Experiment 9 and four months in Experiment 10. Soil samples taken after the harvest of Experiment 9 were analysed for pH, P, K, Ca, Mg, Al and clay %. Ers %, fibre % cane and juice purity were determined at harvest in all three experiments.

Experiment 8 was harvested at 12,8 months (20.10.93 to 15.11.94), Experiment 9 at 10,6 months (15.11.94 to 4.10.95) and Experiment 10 at 12 months (6.11.96 to 13.11.97). Total rainfall for the duration of these crops was 945, 614 and 1 225 mm respectively. The long term mean annual rainfall at the site of Experiments 8 and 9 was 1 003 mm and at Experiment 10 was 1 001 mm.

Results

Experiments 1 to 7 - Maize

Leaf nutrient content

Nitrogen levels in the leaves from the coated urea treatments compared with those from commercial urea, were significantly higher in Experiments 1, 5 and 6 while Ca was lower in Experiment 2 (Table 1). The Ca and Mg values were positively correlated with grain yield increases induced by the coated urea (r = +0,8933** and +0,8922**) and negatively correlated (NS) with total rainfall.

Grain yields

Statistically more grain was produced by the polymer coated urea than commercial urea in Experiments 2 and 3. The magnitudes of differences were negatively correlated with seasonal rainfall (r = –0,5332 NS) (Table 1).

Experiments 8, 9 and 10 - Sugarcane

Leaf nutrient content

Leaves taken at four and six months from Experiment 8 had reduced concentrations of all nutrients when the coated forms of both urea and LAN were compared with the uncoated forms at 80 and 160 kg N/ha (Table 2). After seven months reduced concentrations were still present for K, Ca and Mg % in the 160 kg N/ha urea treatments.

In Experiment 9 leaf P and K values at 160 kg N/ha were higher while Ca values were lower when coated urea was compared with its commercial equivalent (Table 3).

Experiment 10 leaf samples had lower K and Ca values when taken from the coated LAN and urea treatments compared with those from plots which received the commercial products (Table 3).

Cane yield, ers % cane and sugar yield

In Experiment 9 commercial LAN produced more tons cane per hectare than coated urea at 80 kg N/ha. In Experiment 8 coated LAN and coated urea treatments at 80 kg N/ha had a higher ers % cane than commercial urea at 160 kg N/ha. In Experiment 10, the Brix % juice was higher in the coated urea at 160 kg N/ha compared with commercial urea and LAN at the same rate (20,5% versus 20% – not reported here).

Experiment 8 showed higher ers %, and pol % cane values in the polymer coated urea and LAN treatments at 80 kg N/ha when compared with commercial urea at 160 kg N/ha (Tables 2 and 6).

Purity %, fibre % and dry matter % cane

In Experiment 10 purity % of cane was higher in the polymer coated LAN treatment compared with the polymer coated urea treatment (Table 5). Experiment 8 showed that fibre % and DM % cane were higher in coated urea versus commercial urea at 160 kg N/ha (Table 5).

Borer damage

The percentage stalks bored by *Eldana saccharina* Walker (Lepidoptera: Pyralidae) was higher with commercial urea at 160 kg N/ha than with commercial urea, commercial LAN and coated LAN at 80 kg N/ha (Table 3). Stalks from fields treated with the polymer coated urea at 160 kg N/ha had similar levels of damage as fields treated with other fertilisers at 80 kg N/ha.

Soil composition

Soil pH values were lower in plots that received commercial urea at 160 kg N/ha compared with those receiving coated urea and coated LAN at 80 kg N/ha. The Al contents of the composite soil samples were consistently lower where the coated urea and LAN fertilisers were applied.

Table 1. Grain yields, seasonal rainfalls and leaf contents of N, Ca and Mg from Experiments 1 to 7.

Expt No.	Season	Grain yields (t/ha)		Seasonal rainfall Oct to Feb incl mm (%)	Leaf N %		Leaf Ca %		Leaf Mg %	
		Comml urea	Coated minus Comml		Comml urea	Coated minus Comml	Comml urea	Coated minus Comml	Comml urea	Coated minus Comml
		A	B	C	D	E	F	G	H	I
1	1987-88	6,30	–0,20	603 (98)	2,13	+0,25*	0,35	+0,02	0,19	+0,02
2	1988-89	7,30	+0,8*	797 (130)	2,71	+0,05	0,50	–0,04*	0,27	–0,02
3	1989-90	1,60	+1,7*	559 (91)	2,43	–0,04	0,50	–0,02	0,30	0,00
4	1990-91	Hail	Hail	727 (118)	2,50	–0,01	0,30	0,00	0,21	0,00
5	1991-92	5,90	+0,7	549 (89)	2,51	+0,28**	0,41	+0,05	0,18	+0,01
6	1992-93	7,60	+0,4	573 (93)	2,92	+0,28*	0,41	–0,01	0,25	–0,01
7	1993-94	9,00	+0,2	895 (146)	2,39	+0,10	0,36	+0,01	0,19	0,00
	26 year mean	–	–	615 (100)	–	–	–	–	–	–
r Values:	A Versus	–	–	+0,6506	+0,2057	–	–0,5723	–	– 0,5614	–
	B Versus	–	–	–0,5532	–	–	+0,8933**	–	+0,8922**	–

Cmml = Commercial

Discussion

Leaf analyses from sugarcane experiments showed that generally lower N values were obtained from ratoon crops grown in untilled soils when polymer coated urea and LAN were used (Table 2 and Bishop, 1977). This was to be expected because of the reduced solubility of the coated prills. The contradictory results recorded in Experiments 1, 5 and 6, where coated fertilisers were used with maize, showed unexpectedly higher leaf N% values. These increases equated to an extra 84 kg/ha of plant available N in the plots which received 40 kg/ha coated urea instead of the commercial form (Bishop, 1993), and explain the higher protein contents in winter wheat grain over 3 seasons (Els and Potgieter, 1991). This was considered attributable to the side effects of extra N being made available by micro-organisms in the recently tilled soils (Wood, 1979).

Table 2. Leaf analyses from Experiment 8 at 4, 6 and 7 months of age.

N applied	4 months					6 months					7 months				
80 kg/ha	N%	P%	K%	Ca%	Mg%	N%	P%	K%	Ca%	Mg%	N%	P%	K%	Ca%	Mg%
E Comml LAN	1,75	0,23	1,16	0,22	0,17	1,67	0,20	1,31	0,22	0,17	1,99	0,22	1,64	0,35	0,23
F Poly coated LAN (0,5% on LAN)	1,73	0,23	1,15	0,22	0,16	1,57	0,17**	1,24	0,21	0,17	1,97	0,22	1,51	0,37	0,23
G Cmml urea	1,77	0,23	1,14	0,23	0,17	1,68	0,20	1,31	0,23	0,18	1,95	0,22	1,58	0,34	0,23
H Poly coated urea (0,5% on urea)	1,65*	0,21*	1,07*	0,22	0,16	1,58	0,19	1,24	0,21	0,17	2,05	0,22	1,50	0,37	0,24
160 kg/ha I Cmml urea	1,75	0,24	1,20	0,23	0,18	1,79	0,20	1,38	0,26	0,18	2,00	0,22	1,71	0,42	0,24
J Poly coated urea (0,5% on urea)	1,71	0,22*	1,13*	0,21*	0,16*	1,64*	0,19	1,29	0,21**	0,17	1,94	0,22	1,55*	0,37*	0,22*
CV% LSD 5% LSD 1%	4,4 0,08 0,11	6,3 0,01 0,01	6,1 0,07 0,09	11 0,02 0,03	8,4 0,02 0,03	7,7 0,13 0,18	10,9 0,02 0,03	7,4 0,1 0,13	14,3 0,03 0,04	8,6 0,02 0,03	6,3 0,12 0,16	4,7 0,01 0,01	8,8 0,14 0,19	14,9 0,05 0,07	7,8 0,02 0,03

Table 3. Analyses of leaves taken from Experiment 9 and 10, and Eldana damaged stalks in Experiment 9.

N applied	Experiment 9 Leaf contents at 3 months					% stalks bored	Experiment 10 Leaf contents at 6 months†				
80 kg/ha	N%	P%	K%	Ca%	Mg%		N%	P%	K%	Ca%	Mg%
Cmml LAN	2,01	0,20	1,11	0,30	0,20	1,57	–	–	–	–	–
Poly coated LAN (0,5% on LAN)	1,94*	0,20	1,14	0,28	0,19	1,88	1,73	0,20	1,45	0,30	0,21
Cmml urea	1,89	0,19	1,14	0,28	0,20	1,16	–	–	–	–	–
Poly coated urea (0,5% on urea)	1,93	0,20	1,05	0,26	0,21	2,07	1,71	0,22	1,45	0,31	0,22
160 kg/ha Cmml urea	1,98	0,17	1,01	0,31	0,20	3,48	1,87	0,20	1,41	0,32	0,22
Poly coated urea (0,5% on urea)	2,01	0,19*	1,16**	0,25*	0,19	1,95	1,85	0,21	1,32	0,29	0,22
Cmml LAN	–	–	–	–	–	–	1,85	0,22	1,49	0,32	0,22
Poly coated LAN (0,05% on LAN)	–	–	–	–	–	–	1,86	–	–	–	–
CV% LSD 5% LSD 1%	3,40 0,07 0,09	7,00 0,01 0,01	8,90 0,12 0,16	16,50 0,05 0,07	9,00 0,02 0,03	84,90 1,57 2,11	– – –	– – –	– – –	– – –	– – –

†Conducted on composite samples from four replications.

Table 4. Cane yield, ers % cane and ters/ha from Experiments 8, 9 and 10.

Treatments	Cane yield (t/ha)						Ers % cane						Ters/ha					
	Exp 8	Exp 9	Exp10	Exp 8	Exp 9	Exp10	Exp 8	Exp 9	Exp10	Exp 8	Exp 9	Exp10	Exp 8	Exp 9	Exp10	Exp 8	Exp 9	Exp10
	Rat 1	Rat 2	Rat 1	Rat 1	Rat 2	Rat 1	Rat 1	Rat 2	Rat 1	Rat 1	Rat 2	Rat 1	Rat 1	Rat 2	Rat 1	Rat 1	Rat 2	Rat 1
N applied (kg/ha)	80			160			80			160			80			160		
A Cmml LAN	65,7	48,4	–	–	–	114,1	10,57	11,07	–	–	–	14,10	6,9	5,4	–	–	–	16,1
B Poly coated LAN (0,05% on LAN)	60,5	45,3	110,1	–	–	111,7	11,10	11,06	14,33	–	–	14,45	6,7	5,0	15,8	–	–	16,1
C Cmml urea	57,2	40,9	–	62,3	41,6	117,3	10,56	11,13	–	9,73	11,65	14,03	6,0	4,6	–	6,1	4,8	16,5
D Poly coated urea (0,05% on urea)	60,5	39,2	113,3	57,8	41,2	112,8	11,11	11,64	14,18	10,69	11,20	14,38	6,7	4,6	16,1	6,2	4,6	16,2
CV%	20,2	14,9	41,1	20,2	14,9	41,1	9,8	7,9	1,4	9,8	7,9	1,4	22,3	15,5	7,3	22,3	15,5	7,3
LSD 5%	12,2	7,7	7,4	12,2	7,7	7,4	1,05	1,08	0,48	1,05	1,08	0,48	1,43	0,90	1,19	1,43	0,90	1,19
LSD 1%	16,4	10,4	10,0	16,4	10,4	10,0	1,41	1,45	0,65	1,41	1,45	0,65	2,59	1,21	1,60	2,59	1,21	1,60

Table 5. Cane analysis from Experiments 8, 9 and 10.

Treatments	Purity % cane						Fibre % cane						Dry matter % cane					
	Exp 8	Exp 9	Exp10	Exp 8	Exp 9	Exp10	Exp 8	Exp 9	Exp10	Exp 8	Exp 9	Exp10	Exp 8	Exp 9	Exp10	Exp 8	Exp 9	Exp10
	Rat 1	Rat 2	Rat 1	Rat 1	Rat 2	Rat 1	Rat 1	Rat 2	Rat 1	Rat 1	Rat 2	Rat 1	Rat 1	Rat 2	Rat 1	Rat 1	Rat 2	Rat 1
N applied (kg/ha)	80			160			80			160			80			160		
A Cmml LAN	84,9	86,7	–	–	–	95,3	13,8	14,4	–	–	–	–	28,5	29,2	–	–	–	–
B Poly coated LAN (0,05% on LAN)	85,6	86,6	94,9	–	–	95,5	13,6	14,5	–	–	–	–	28,7	29,3	–	–	–	–
C Cmml urea	84,9	87,1	–	82,3	87,0	95,0	13,8	14,6	–	13,1	14,3	–	28,4	29,4	–	27,4	29,7	–
D Poly coated urea (0,05% on urea)	87,5	88,3	95,1	86,3	86,8	94,8	14,3	14,7	–	14,1*	14,2	–	28,9	29,3	–	28,6**	29,1	–
CV%	6,3	1,8	0,4	6,3	6,3	0,4	6,9	3,8		6,9	3,8		2,9	1,9		2,9	1,9	
LSD 5%	6,48	1,94	0,69	6,48	1,94	0,69	0,95	0,54	–	0,95	0,54	–	0,82	0,55	–	0,82	0,55	–
LSD 1%	8,74	2,62	0,92	8,47	2,62	0,92	1,28	0,73		1,28	0,73		1,10	0,74		1,10	0,74	

Results showed that the dominant factor determining yields of both maize and sugar was rainfall, with variances of approximately 400% between wet and dry cycles. The maize grain yields had a positive correlation with total rainfall (r = +0,506 NS) and a negative correlation with leaf Ca (r = –0,5723 NS) and Mg values (r = –0,5614 NS) with both commercial and coated urea. Total rainfall does not take into account distribution which is crucial to grain initiation and development. It is postulated that the levels of leaf Ca and Mg in these experiments reflect the moisture regimes that prevailed at the time of leaf sampling, i.e. at tasselling, when adequate moisture is essential for grain initiations. ([1]personal communication). Grain yield differences between the coated urea and commercial urea were significantly correlated with leaf Ca and Mg values (r = +0,8933** and +0,8922**). This suggests that the crops grown with coated urea resisted moisture stress better at tasselling, possibly because they were more mature (see higher fibre % cane results) and had better developed root systems. Such crops would be better able to withstand periods of temporary drought, but this advantage would be less significant in seasons of abundant rainfall (Experiment 7).

In the sugarcane experiments on undisturbed soils, no differences in tons ers/ha occurred between any two treatments, including the commercial fertilisers at 80 and 160 kg N/ha.

[1]M Farina, Department of Agricultural Development (1997).

Generally higher ratios of ers % cane to tons cane/ha with the coated urea and LAN represented a saving in harvesting and transport costs of up to 5% (Experiment 8). Coated urea and coated LAN generally produced crops with predictably higher ers % and pol % cane, improved juice purity, and increased dry matter % and fibre % cane. The only time a coated fertiliser did not give higher ers % cane was with coated urea at 160 kg N/ha in Experiment 9. The very low rainfall of 33 mm in the three months prior to harvest would have induced more ripening with the commercial urea than occurred in Experiments 8 and 10 where 184 and 247 mm rain respectively, fell in the same period (not recorded here). The higher ers % cane values with increasing applications of coated urea and LAN from 80 to 160 kg/ha in the high rainfall season (Experiment 10) are in contrast to the lower concentrations that traditionally occur with high levels of commercial N fertilisers. At 160 kg N/ha coated LAN also had the highest purity % cane while coated urea had the highest Brix % juice in this experiment. Although the increased ers % cane improved the tons ers/ha of the coated LAN treatment compared with commercial LAN, (NS), commercial urea yielded the highest tons cane, and tons ers/ha in this wettest season (NS). In the drier seasons of Experiments 8 and 9 commercial LAN, and to a lesser extent coated LAN, gave more tons cane/ha than the coated or commercial urea at 80 kg N/ha. The coated urea bettered the yield of commercial urea by 0,7 tons ers/ha (NS) to almost match the highest yielding LAN fertilisers at 80 kg N/ha in Experiment 8 (Table 4). The polymer coated LAN and urea had less of an acidifying effect on the soil than did their commercial equivalents. The higher Ca and Mg contents in the sample from the coated LAN treatment (NS) indicated that a build-up of these nutrients over the two ratoons may have occurred, when compared with the levels in the soils which received commercial LAN, urea and coated urea. The reduced Eldana damage recorded with the polymer coated urea at 160 kg N/ha in Experiment 9, while not statistically significant when compared with commercial urea at the same rate, may be due to the higher fibre % cane and warrants further investigation.

It is postulated that the more restrained rate of N release from the fertilisers coated with 0,5% polymer (Table 2) produced hardier, less vegetative crops than those produced by commercial N. Evidence of this was that, in maize, the biggest difference in grain yield occurred in the season of lowest yields and that, in sugarcane, sticks with higher fibre content at harvest (Table 5) and leaves with lower concentrations of N, P, K, Ca and Mg at four months (Table 2), were recorded. The production of maize crops with lower ratios of stover to grain (Bishop, 1993) and of sugarcane crops with lower ratios of tons cane to ers % cane (Table 4) is an indication that the predominantly vegetative stimulus produced by commercial N is tempered by the polymer coating around the urea and LAN prills. The lower level of available N that resulted from the restrained rate of release that occurred in untilled soils was reversed in tilled soils in those seasons which were favourable to the development of N mineralising soil microbes. This resulted in substantially higher levels of available N where the coated urea was compared with commercial urea at 40 kg N/ha, as evidenced in Experiments 1, 5 and 6. The extra N can only be explained by the occurrence of greater activity by N mineralising bacteria in the soil. The more biologically hospitable soil environment which resulted from the reduced acidification of soil (Table 6) and higher temperatures (±4°C) that the polymer induced in wet soils as a result of reduced evaporation (Bishop, 1977) could account for this. This glass-house effect in the early part of the season, when soil temperatures may be borderline in wet soils, would be particularly conducive to vigorous growth. Although an extra supply of N could be detrimental to the potential increase in

Table 6. Analyses of soils from Experiment 9, taken after harvest.

N applied	pH (water)	P ppm	K ppm	Ca ppm	Mg ppm	Al ppm†	Clay %
			80 kg N/ha				
Cmml LAN	5,24	34	123	252	89	14,5	19
Poly coated LAN (0,5% on LAN)	5,51	35	165	470	109	11,5	22
Cmml urea	5,28	35	94	288	108	15,0	19
Poly coated urea (0,5% on urea)	5,46	27	100	285	98	12,0	19
			160 kg N/ha				
Cmml urea	5,09	29	97	222	78	14,2	19
Poly coated urea (0,5% on urea)	5,37	24	94	196	62	12,0	17
CV%	6,7	39,3	69,3	83	55		29,2
LSD 5%	0,36	12,1	77,6	285,2	49,8		5,5
LSD 1%	0,48	16,3	104,2	383	66,9		7,4

†Composite samples from six replications.

maize grain and ers % cane, resulting from the controlled release provided by the coated fertilisers in seasons of low mineralisation, increased yields of stover, cane and protein would compensate for this.

Conclusions

The maize and sugarcane results indicate that urea and LAN prills coated with low levels of polymer (less than 600 g/ha) are capable of producing crops with very different characteristics to their commercial equivalents. Possible reasons for this effect are the reduced, but apparently adequate, rates of N solubilised soon after application. In cultivated soils where climatic conditions are borderline for the development of N mineralising micro-organisms, the coated fertilisers enable the generation of substantial amounts of additional plant available N compared with commercial fertilisers. The subsequent increased protein contents of grain and foliage would be of particular benefit in crops requiring this property, e.g. fodder. Maximum grain response from coated urea at 40 kg N/ha occurred in one of the driest seasons, and this fertiliser would be particularly useful for grain production in areas of low rainfall. In sugarcane ratoons, higher ers % cane and juice purity values resulting from the use of coated urea or LAN would result in greater efficiency in the handling and transport of the crop and processing at the mill. High rates (160 kg N/ha) of coated urea and LAN did not depress ers % cane, purity and Brix % juice, fibre % cane and soil pH as much as did their commercial equivalents, and heavier applications of these fertilisers should be tried in high production areas.

Altered characteristics induced by the coated fertilisers include increased ers % and fibre % in crops of the same age and crops with lower N but higher fibre contents that appear to be better able to withstand pests. These characteristics would be advantageous in the cultivation of other crops. Fertiliser prills coated with styrene-octyl acrylic polymers had anti-caking properties comparable with commercial prills coated with other anti-caking chemicals ([2]personal communication), but had the additional advantage of producing less acidification in the soils to which they were applied. This positive effect on the environment is in itself sufficient reason to warrant investigation into the use of styrene-octyl acrylic polymers as the preferred anti-caking agent.

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[2]BA McAlpin, Revertex Chemicals (Pty) Ltd (1997).

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REFERENCES

Bishop, RT (1977). Soils modified with polymer emulsions as substitutes for polyethylene sheet. *Proc S Afr Sug Technol Ass* 51: 57-61.

Bishop, RT (1992). Factors affecting the ability of polymer sprays to increase the yields and nutrient uptakes of maize. *21st S Afr Soc Crop Prod Symp,* Golden Gate. 16 pp.

Bishop, RT (1993). Increased efficiency of nitrogen fertilisers when combined with polymers. *Proc S Afr Sug Technol Ass* 67: 53-56.

Els, P and Potgieter, F (1991). The effectiveness of Revlan 2 as a source of slow release nitrogen. *Western Province Co-operative, Malmesbury,* 2 pp.

Wood, RA (1979). The effects of lime on release and plant uptake of nitrogen from soils of the Natal Midlands. *Proc S Afr Sug Technol Ass* 53: 173-176.