INCREASED EFFICIENCY OF NITROGEN FERTILISERS WHEN COMBINED WITH POLYMERS

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Abstract

Two field trials with maize and sugarcane are described in which different rates of N fertilisers were applied. Treatments included commercially available limestone ammonium nitrate (LAN) and urea, styrene-octyl acrylic polymer coated LAN and urea, and soil applied polymer spray in combination with LAN and urea. Leaf analyses indicated that all the polymer treatments increased plant available N, compared with commercial LAN and urea, when applied to recently tilled soil. The treatments using coated urea and the spray of polymer combined with normal LAN showed the greatest increases in plant available N (about 80 kg N/ha). Although the LAN coated with the high level of polymer produced only an additional 33 kg N/ha, it gave the most consistent increases in maize grain (0,9 tons/ha, or 15%) and estimated recoverable sugar (1,9 tons/ha, or 18%).

Introduction

Two trials with plant cane (Bishop and Kruger, 1979; Moberly, 1983) showed that substantial applications (33 kg/ha) of a styrene-octyl acrylic polymer emulsion (Reverseal 5/1) to the soil surface, or in the furrow at planting, resulted in increased tillering (+39% in one instance) and higher estimated recoverable sugar (ers) values (increases of 2,3 and 1,2 tons ers/ha respectively) compared with the control treatments, where no polymer was applied. The reason for these increases was initially thought to be due to improved soil moisture, resulting from the unbroken ±25 mm thick layer of polymer-consolidated soil acting as a polyethylene film (Bishop, 1977). Subsequent field trials indicated that the yield boosting effect of the polymer was neutralised when high rates of N fertiliser were applied (Bishop, 1991). It was thought that the combination of a high concentration of moisture and the applied N under the consolidated soil crust encouraged the build-up of populations of undesirable micro-organisms (Trolldenier, 1969). To overcome this problem two modifications were made: firstly, the rate of polymer spray was reduced so that broken crusts were formed and, secondly, prills (crystals) of N fertilisers were coated with polymer to reduce excessively high concentrations of soluble N in the soil. These techniques used alone, or in combination (where their effects were cumulative), gave significant increases in per cent leaf N values and plant yields in *Eucalyptus grandis* (Donald, 1987), wheat grain (Els and Potgieter, 1991), and maize leaves (Bishop, 1991; 1992). Although a polymer coating of 1,0% on LAN produced significant yield responses in maize when applied at rates of 80 to 120 kg N/ha, the same coating mass around urea prills resulted in significant yield increases only at the low rate of applied N (40 kg N/ha) (Bishop, 1991). The aim of this investigation was to compare those polymer treatments that had previously resulted in increased leaf N values and crop yields. Maize and ratoon cane were used as indicator crops.

Procedures

Experiment 1 - Maize

The experiment site was located on an Avalon series soil at Dundee, northern Natal. The design was a randomised block with five replications and the plant used was maize, variety HI 3442. Seven different treatments were applied, each at five rates of N (Table 1). Commercially available LAN and urea prills were coated with 0,01% and 1,0% polymer by spraying different concentrations of the liquid onto the prills while they were tumbling in a concrete mixer. The inclusion of a dye showed that coating was complete in less than five minutes. The equivalent of 95 kg P/ha and 50 kg K/ha were broadcast over the test area. The N fertiliser treatments were split: half was applied before planting and the balance when the maize was about 0,5 m tall. The polymer spray treatments were applied over the row before germination (treatments D and G) and again after five weeks (treatment C) using the polymer emulsion diluted 120 and 200 times respectively. The numbers of plants tillering in each plot were counted. Leaf samples were taken at the tasselling stage (11 weeks after planting), and analysed for N. At harvest the mass of grain and stover (leaves and stalks), and the populations of cobs and stalks, were recorded. One replication was omitted because certain plots were poorly drained. The 1991-92 season was characterised by good rains up to the tasselling stage (mid-December), followed by hot dry conditions in January and February. Although good cob initiation was achieved, the late drought curtailed development of the grain.

Experiment 2 - Sugarcane

Polymer spray and polymer-coated LAN (0,01% and 0,5%) and urea (0,5% only) treatments similar to those that gave good yield increases in Experiment 1, were tested on a fourth ratoon crop of sugarcane at Ellingham Estates on the Natal south coast. The experiment design was a randomised block with five replications. The soil was of the Glenrosa form and the cane variety was NCo376. Trash was removed from the test site. Phosphorus (P) and potassium (K) were applied to all plots at rates of 35 kg P/ha and 124 kg K/ha respectively. The commercial and polymer-coated N fertilisers (Table 2) were then applied as an onrow top-dressing to the ratooning cane. Because the trial was in a field of commercially grown cane no zero or 40 kg N/ha treatments were included. Immediately after the fertilisers were applied, the polymer emulsion at a rate of 1 kg/ha was sprayed in a 0,5 m wide band over the rows of plants in one half of each plot. Third leaf N values were determined from samples taken when the cane was four and seven months old. Ers % cane, grams ers per stalk, fibre per cent and purity were determined at harvest.

Results

Experiment 1 - Maize

Leaf N content

The mean N contents of leaf samples taken at tasselling are given in Table 1. Based on LAN, the mean N content

Table 1

Leaf N content and maize yield from Experiment 1

Treatments	Leaf N (%)					Yield (tons/ha)					Ratio of grain to stover yield				
N applied (kg/ha)	0	40	80	120	160	0	40	80	120	160	0	40	80	120	160
A Commercial LAN	2, 8	2,61	2,77	2,07	3,01	5,7	8,0	6,2	7,2	4,8	1,5	1,2	1,1	1,2	1,1
D Polymer spray with LAN at planting 740 g/ha	2,64	2,76	2,74	2,91	3,05	5,6	6,5	6,4	6,3	5,5*	1,6	1,2	1,1	1,0*	0,9*
C Polymer spray with LAN after 5 weeks 600 g/ha	2,52	2,68	2,9	2,92	2,92	5,8	6,3	5,8	6,7	6,5	1,5	1,4*	1,1	1,1	1,1
G Polymer coated LAN Thin coat 0,01% + Treat D	2,64	2,82	2,74	2,96	2,95	5,6	6,70	7,2*	7,0	7,1	1,6	1,4*	1,3*	1,1	1,1
E Polymer coated LAN Thick coat 1,0%	2,48	2,70	2,86	2,98	2,97	5,7	5,70	7,1	7,4	5,9	1,5	1,1	1,2	1,2	1,0
B Commercial urea	2,48	2,51	2,82	2,97	2,94	5,7	5,0	6,9	6,5	6,1	1,5	1,3	1,3	1,1	1,1
F Polymer coated urea Thick coat 1,0%	2,48	2,79*	2,81	2,88	3,00	5,7	6,6	7,1	6,3	7,4*	1,5	1,3	1,3	1,0	1,2
CV (%)	6,3					13,2					14,4				
LSD 5%	0,23					1,0					0,2				
LSD 1%	0,30					1,2					0,2				

Table 2

Leaf N values and cane yield from Experiment 2

Treatments		Leaf N%				Cane yield (t/ha)		ers % cane		Sugar yield			
		4 months		7 months						tons ers/ha		g ers/stalk	
N applied (kg/ha)		80	120	80	120	80	120	80	120	80	120	80	120
A Commercial LAN	Alone	>2,31	2,42	1,70	1,85	76,9	84,2	13,18	12,29	10,3	10,4	74,2	80,2
	Spray			1,62*	1,73**	76,9	83,4	12,62	12,75	9,7	10,6	74,1	76,1
B Polymer coated LAN (Thin coating 0,01%)	Alone	>2,27	2,36	1,71	1,81	92,7*	84,2	12,97	12,91	12,0*	10,9	80,4	86,6
	Spray			1,67	1,69**	84,8	82,9	13,37	13,04	11,4	10,8	83,1	77,1
C Polymer coated LAN (Thick coating 0,5%)	Alone	>2,32	2,33	1,72	1,83	83,0*	91,3	13,74	13,45*	11,4	12,3*	88,4*	90,0
	Spray			1,62*	1,73**	81,9	85,6	13,56	13,36	11,1	11,5	92,9**	77,6*
D Commercial urea	Alone	>2,21	–	1,73	–	84,3	–	13,18	–	11,1	–	86,6	–
	Spray			1,69	–	80,1	–	13,86	–	11,1	–	85,7	–
E Polymer coated urea Thick coating 0,5%)	Alone	>2,42**	–	1,66*	–	76,9	–	13,38	–	10,3	–	87,9	–
	Spray			1,68	–	74,7	–	13,72	–	10,3	–	97,9**	–
CV (%)		5,0		4,4		11,3		4,7		9,8		11,5	
LSD 5%		0,1		0,07		9,3		1,10		1,5		11,9	
LSD 1%		0,14		0,09		12,3		1,48		2,0		16,0	

at tasselling correlated well with applied N ($r = 0,985$). The 0,53 percentage unit difference in leaf N values between the control treatment (zero N) and the 160 kg N/ha treatment, in this case, represented an increase of 0,01% N for every additional 3,02 kg N/ha applied. At the 40 kg N/ha rate, the polymer-coated urea resulted in a mean leaf N value of 2,79%, which was significantly higher than that of the untreated urea (2,51% N). The difference of 0,28% represented an apparent additional 85 kg N/ha. There were no significant differences in leaf N values between the various LAN/polymer treatments (Table 1). However, the leaf N contents associated with the soil-applied polymer spray in combination with commercial LAN (treatment D) and polymer-coated LAN (treatment G) were also significantly higher than those of the untreated urea.

Grain yield

At 80 kg N/ha, the 0,01% polymer-coated LAN plus polymer spray in treatment G yielded statistically more grain (1,0 tons/ha, or 16%) than did commercial LAN (Table 1). Both the polymer-coated LAN treatments also produced more cobs per hectare than commercial LAN at 80 kg N/ha (Bishop, 1993). At 160 kg N/ha the polymer-coated urea treatment (F), yielded significantly more grain (1,3 tons/ha, or 20%) and cobs (9 000/ha, or 21%) than commercial urea, where yield was depressed. This yield depressing effect at high levels of commercial N fertilisers occurred to an even greater extent in treatment D (commercial LAN with polymer spray at planting). In contrast, when the 0,01% polymer-coated LAN prills were used with the spray (treatment G), the yield depressing effect of 1,1 ton/ha (–17%) shown in treatment D, became a gain of 0,5 tons/ha, or 6 000 more cobs per hectare, when compared with commercial LAN. This grain yield difference of 1,6 tons/ha, due to the presence of 57 g/ha of polymer on 570 kg/ha of LAN, was statistically significant at the 1% level.

Ratio of grain to stover yield

The reduced ratio of grain to stover at the higher rates of applied N were expected (treatments A and B in Table 1), as vegetative growth had been stimulated during the early growing season, but drought had curtailed the development of the grain. The ratios were further reduced when the polymer spray was applied at planting with commercial LAN, presumably due to the higher levels of plant available N (treatment D). In contrast, the proportion of grain yielded was enhanced when spraying at 40 kg N/ha was delayed five weeks, or when the 0,01% coated LAN replaced commercial LAN (40 and 80 kg N/ha). The high grain yielding 1,0% polymer-coated LAN (120 kg N/ha) and urea (160 kg N/ha) treatments had grain to stover ratios similar to their untreated controls and produced the highest total plant yields in the experiment (Bishop, 1993).

Experiment 2 – Sugarcane

Leaf N content

The N contents of sugarcane leaves sampled at four and seven months are shown in Table 2. Trends in leaf samples from the whole plots at four months were (i) the 0,5% polymer-coated urea (treatment E) at 80 kg N/ha, which had a significantly higher leaf N content than either commercial urea or LAN; and (ii) the 0,01% and 0,5% coated LAN (treatments B and C) at 120 kg N/ha, which had leaf N values which decreased with increasing mass of the polymer coatings, thus reflecting the reduced solubilities of the prills. At seven months the leaf N values in the 0,5% polymer-coated urea treatments contained significantly less N than the control, while N concentrations in leaves from the 0,5% polymer-coated LAN matched that of the control. In all LAN treatments the leaf N values were lower in the half-plots that received the polymer spray.

Estimated recoverable sugar

At 120 kg N/ha the 0,5% polymer-coated LAN increased sucrose concentration (ers % cane) compared with commercial LAN (Table 2). Grams ers/stalk were increased by the 0,5% polymer coating on LAN (with or without the polymer spray) and urea (only in combination with the spray).

Cane yield and sugar yield

Only treatment B (0,01% polymer-coated LAN) at 80 kg N/ha yielded significantly more cane (15,8 tons/ha, or 20%) than commercial LAN (Table 2). Both the polymer-coated LAN treatments produced significantly more tons ers/ha than commercial LAN at equivalent rates (Table 2). Treatment B (80 kg N/ha) yielded 1,7 t ers/ha (16%) more, whereas the more heavily coated treatment C (120 kg N/ha) gave 1,9 t ers/ha (18%) more.

Discussion

Commercial LAN and urea reduced grain yields in maize and ers % values in sugarcane when optimum levels of application were exceeded. These reductions were minimised when prills of LAN or urea were coated with styrene-octyl acrylate polymer, which effectively reduced the amounts of soluble N entering the soil. The coated fertilisers appear to increase substantially the quantities of plant available N, assuming other soils behave in a manner similar to the Avalon series soil at Dundee. The styrene-octyl acrylic polymer sprayed on the soil was able to produce a similar increase in plant available nitrogen, but did not control N release rates, as did the coated prills.

The sprays of the chemically inert polymer could have achieved the indicated increases in plant available N in the zero N plots of Experiment 1 by only physical means, and the small amount applied would not noticeably have affected soil structure. The observation that treated particles become hydrophobic on drying out suggests that numerous microscopic dry spots in a wet soil result in localised zones having slightly higher temperatures (Bishop, 1977). These zones benefit those soil microbes mineralising N from organic matter (Wood, 1979) but are unlikely to have a direct effect on plants. Critical temperature differences in microbial activity might explain the observed increases in plant available N in the zero N plots of Experiment 1. The earlier tillering and subsequent increased yields which followed the first rains in the polymer-sprayed plots can possibly be attributed to higher levels of microbially generated N rather than to moisture conservation as originally postulated. The fact that the polymer spray at 1 kg/ha in the ratoon crop of Experiment 2 reduced leaf N values compared with those of the control, suggests that the application rate should have been only about 0,1 kg/ha (Bishop, 1992) and on to recently tilled soil. The rough surface of the tilled soil would result in a discontinuous film of polymer affected soil particles as opposed to the impervious sheet that normally occurs after spraying a typically smooth soil surface in a ratoon crop.

The ability of the polymer-coated prills to maintain yields of grain and sugar at high application rates of LAN is thought to be due to the slower N release rate, which would optimise supplies of N to plants and microbes. The fact that the soil immediately around the coated LAN and urea prills becomes hydrophobic once the fertilisers are leached away (Bishop, 1977) suggests that the temperature enhancing effects described with the polymer spray, also occurred here.

Conclusions

Maximum sugar yield response from coated fertilisers occurred with 0,5% polymer at 120 kg N/ha of LAN. Linear yield improvements with LAN prills coated with increasing amounts of polymer, at 120 kg N/ha, indicated that higher yields would result from greater coating mass. This was confirmed in Experiment 1 where good yield results were obtained with 1% polymer. For sub-economic areas, where N applications are 40 kg N/ha or less, indications are that a substantial source of additional plant available N could be accessed either by the polymer spray at planting, or the 1% polymer-coated urea.

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