Is maize silage and grain yield and N concentration affected by method of N fertiliser application?

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Abstract

Over the last few years maize growers have expressed an interest in more cost-effective and sustainable crop management practices, especially nitrogen fertiliser use, and here we investigate the effect of different N management strategies on maize silage and grain yields and N concentration. The four-fold replicated split plot experiment compared two irrigation regimes (minimal and heavy) and five N fertiliser treatments, a control and four methods of applying 350 kg N/ha. Yield and N concentration of maize silage, grain and crop residues were measured. A winter cover crop of oats was sown to determine any carry over effect of the treatments. The irrigation treatment did not effect maize silage or grain yields. The control silage yields were significantly less than all fertilised treatments but maize silage and grain yields were similar for plots that received N fertiliser, thus fertiliser application method did not affect yields. Irrigation treatment did not affect crop nitrogen concentration but fertiliser had a large effect on N concentration of the silage, grain and crop residue. Plant N concentration at both silage and grain harvest was least in the control plots and highest where all fertiliser was applied at planting, but this probably luxury N uptake by these treatments as no yield advantage accrued. The yield of the subsequent winter cover crop was significantly higher in the fertilised plot compared with the control.

Introduction

Over the last few years maize growers have expressed an interest in more cost-effective and sustainable crop management practices, especially nitrogen fertiliser use. Recently decision support software has been developed for the maize grain industry to assist growers determine fertiliser nitrogen (N) requirements (Reid *et al.,* 1999). However, this software concentrates on optimising fertiliser N and grain yield. Silage yield and plant N concentration are not considered, and neither is fertiliser timing because an earlier study showed no effect on maize grain yield (Stone *et al.*, 1999).

The profitability of maize production can be reduced by losses of N through leaching. In 2002 we began research to help growers improve N fertiliser efficiency by investigating N fertiliser management under leached and non-leached conditions with the overall aim of enhancing economic and environmental performance of cropping practices through better crop yield and quality. While nitrogen leaching was the main focus of the study, the objective of the work reported here is to quantify the effects of different N management strategies on maize silage and grain yields and N concentration.

Methods and Materials

The trial was conducted at Crop & Food Research, Lawn Road, Hastings on a site with a history of long term cropping (soil type Mangateretere silty clay loam, field capacity to 100 mm is 380 mm). The crop (Pioneer hybrid 38G43) was sown by hand on 26 November 2002 at a population of 94 000 plants/ha (76 cm row spacing). Soil mineral N (0-30 cm) (Blakemore *et al.*, 1987) was 81 kg N/ha and base fertiliser of 30 kg P/ha and 30 kg K/ha was broadcast and incorporated at planting to ensure these nutrients were not limiting.

The four fold replicated split plot experiment compared two irrigation regimes (main plot 4.5 x 30 m) and five N fertiliser (sub plot 4.5 x 6 m) treatments. The irrigation treatments were minimal irrigation (76 mm) to maintain soil moisture above a deficit of 30-80 mm, and additional heavy irrigation designed to simulate heavy rainfall and cause leaching in early January (116 mm) and early February (111 mm). All irrigation was applied via drip tape along both sides of each maize row. Total rainfall from planting to silage harvest was 110 mm and from planting to grain harvest was 240 mm.

All N fertiliser was banded next to the plants (5 cm to one side and 5 cm deep) and the treatments were

- Control, no N fertiliser
- 350 kg N/ha urea banded at planting
- 350 kg N/ha slow release urea (Ballance Multicote 41% N) banded at planting
- 350 kg N/ha urea, ⅓ banded at planting, ⅔ side-dressed at six weeks as per normal commercial practice
- 200 kg N/ha urea applied monthly at 50 kg N/ha from planting. Seven applications of 50 kg N/ha were planned but side-dressing late in the season would have damaged the crop.

The crop was harvested for silage on 7 April 2003 (132 DAS) by counting, removing and weighing all plants from a 4.2 m length of row in each plot. Representative plant sub-samples were collected for moisture content and total N concentration. Grain harvest on 28 May 2003 (183 DAS) used the same method but plants were partitioned into grain and crop residue (i.e. non-grain plant material) for total weights, moisture and total N concentration. Grain yields were reported at 14% moisture content and crop residue at 0% moisture. Silage, grain and crop residue samples were dried at 70 °C to a constant weight for moisture content determination and subsequently analysed for total N on a LECO CNS analyser.

After experimental grain harvest, the remaining plants were commercially harvested for grain. The crop residues were mulched and left on the soil surface. A winter cover crop of oats was sown in June 2003 into the control and ⅓ planting, ⅔ side-dressed urea plots of both irrigation regimes. Cover crop yields were assessed on 29 October 2003 by removing all plant material within a one m^2 quadrat, weighing total fresh mass then collecting a representative sub sample for moisture content. All crop yields were statistically analysed by split plot ANOVA using Genstat 6.1.

Results and Discussion

The irrigation treatment did not effect maize silage or grain yields, suggesting the minimal irrigation that was across all plots provided sufficient soil moisture to not limit crop yield and that insufficient N was leached from the heavily irrigated plots to cause yield losses. (Table 1).

The control silage yields were significantly less than all fertilised treatments. Grain yields were significantly more than the control when all N was applied at planting. However, no clear benefit was apparent to grain yields from split applications of N. The average silage yield from fertilised plots was 27.4 t DM/ha, which was more than the average of 19.6 t DM/ha measured in a national survey of 530 silage crops (Kolver *et al.*, 2003).

Table 1. Crop yields (t DM/ha) for silage and grain harvests

	Silage	Final Harvest		
		Grain (14% moist)	Crop Residue	Total Crop
Main plot				
Minimal irrigation	27.1	14.8	12.8	25.6
Heavy irrigation	26.6	14.9	13.5	26.4
Significance	NS	NS	NS	NS
Sub plot				
Control, no N fertiliser	24.6 a	14.1 a	13.0	25.1
350 kg N/ha urea at planting	28.3 b	15.2 b	13.1	26.2
350 kg N/ha slow release urea at planting	27.0 b	15.2 b	13.2	26.3
350 kg N/ha urea, ⅓ planting, ⅔ at six weeks	27.2 b	15.0 ab	13.3	26.2
200 kg N/ha urea applied monthly at 50 kg N/ha	27.2 b	14.9 ab	13.4	26.2
Significance	P=0.001	P=0.116	NS	NS
$LSD_{0.05}$	1.6	0.9		
Interaction	NS	NS	NS	NS

There was no difference in silage and grain yield between treatments that received 200 kg N/ha and those which received 350 kg N/ha. For this particular crop, 200 kg N/ha (split over four applications) was adequate for plant requirements. As crop yields were similar for plots that received nitrogen fertiliser, fertiliser application method did not affect maize silage or grain yields.

Irrigation treatment did not affect crop nitrogen concentration. This suggests the minimal irrigation applied across all plots ensured N uptake by the maize crop was not limited by dry soil conditions, and any N lost by leaching from the heavily irrigated plots was not sufficient to critically reduce N availability. (Table 2).

Fertiliser N had a large effect on N concentration of the silage, grain and crop residue. By grain harvest around twice as much N was stored in the grain than the crop residue, but the N concentration of the crop residue appeared more responsive to N fertiliser than the grain. The control plots had the lowest N concentration at both silage and grain harvest. In the fertilised plots there was an effect of application method on crop N concentration which was highest where all fertiliser was applied at planting, and was probably due to the longer exposure time to high levels of fertiliser nitrogen. The average N concentration of silage from fertilised plots equates to around 6.6 % crude protein, slightly less than that the average of 7.6 % crude protein measured in a national survey of 530 silage crops (Kolver *et al.*, 2003).

Table 2. Crop nitrogen concentration (%) for silage and grain harvests

	Silage	Final Harvest		
		Grain	Crop Residue	Total Crop
Main plot				
Minimal irrigation	0.97	1.41	0.69	1.05
Heavy irrigation	0.97	1.42	0.69	1.04
Significance	NS	NS	NS	NS
Sub plot				
Control, no N fertiliser	0.77 a	1.32 a	0.56 a	0.92 a
350 kg N/ha urea at planting	1.11 c	1.48 b	0.78 d	1.13 c
350 kg N/ha slow release urea at planting	1.05 bc	1.46 b	0.79 d	1.12 c
350 kg N/ha urea, ⅓ planting, ⅔ at six weeks	0.96 b	1.42 b	0.62 b	1.02 b
200 kg N/ha urea applied monthly at 50 kg N/ha	0.95 b	1.42 b	0.70 c	1.05 b
Significance	$P<0.001$	$P<0.001$	$P<0.001$	$P<0.001$
$LSD_{0.05}$	0.11	0.06	0.06	0.05
Interaction	NS	NS	NS	NS

Table 3. Post trial winter cover crop yields (kg DM/ha)

	Oat cover crop (kg DM/ha)
Main plot	
Minimal irrigation	1672
Heavy irrigation	1312
Significance	NS
Sub plot	
Control, no N fertiliser	1214 a
350 kg N/ha urea, ⅓ planting, ⅔ at six weeks	1770 b
Significance	$P<0.05$
$LSD_{0.05}$	426
Interaction	NS

Total crop N uptake was calculated by multiplying yield by N concentration. As irrigation treatment had no effect on yield or N concentration, crop N uptake was also unaffected (data not shown). Fertiliser N had a large effect on N uptake in both silage and grain. The control plots took up the least amount of nitrogen while crop N uptake was greatest where all N was applied all at planting. This result was insensitive to the form of urea, and was due to higher total plant N concentration (rather than yield) in the treatments that received all the N fertiliser at planting. The fertilised plots took up less N than the total amount applied, and the difference of between 50 and 80 kg N/ha would have been available for the following crop unless lost by leaching or volatilization. The yield of the subsequent winter cover crop of oats was significantly higher in the fertilised plot compared with the control plot (Table 3).

Conclusions

The irrigation treatments had little effect on maize growth in this trial. There was no effect on crop yield or N concentration. This suggests there was insufficient drainage to leach N below the rooting zone and/or the soil was not dry enough in the minimal irrigation treatment to limit crop yields or reduce the availability of N. The soil used has a high water holding capacity and the heavy irrigation events were ineffective in inducing leaching losses that would affect crop N availability.

The N fertiliser treatments had the greatest effect on crop yields. As expected, the unfertilised treatments had a significantly lower yield (silage and grain) and a lower N concentration than the fertilised treatments. Due to the high N rate (350 kg N/ha), there were no differences in silage or grain yield among N fertilised treatments. However the method of fertiliser application did affect crop N concentration, particularly the crop residue. The N concentration was highest when all the N was applied at planting, but this was probably luxury N uptake by these treatments as no yield advantage accrued.

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