Effects of N-fertilizer rate and placement on wheat (*Triticum aestivum*) establishment, growth and yield.

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Abstract

In the 2000 and 2001 growing seasons, field experiments evaluating the effects of N-fertilizer rate and placement on establishment, growth and grain yield of wheat were undertaken at Roseworthy, South Australia. Wheat seedling establishment was significantly reduced in 2000 (85%) and 2001 (67%) when high rates of N-fertilizer were placed with the seed. However, toxicity was mostly (2000) or partially (2001) avoided when high rates of N-fertilizer were either banded below or to the side of the seed providing adequate separation between seed and fertiliser. In 2000, there was evidence of high N uptake when banded N increased dry matter (DM) production, however there were no corresponding grain yield or protein benefits. In the 2001 season, there were small N-fertilizer responses in grain yield and protein. However, irrespective of N placement, the crop did not benefit from amounts of N input potentially put in the canopy. From a practical view this study has shown that one-off applications of N-fertilizer, although safer when banded did not necessarily position the crop for higher yields and or protein.

Media summary

High rates of N-fertilizer can be safely banded below or to the side of the seed, avoiding fertilizer toxicity. However, the benefits of one-off applications of N-fertilizer remain unclear, given no large grain yield and or protein responses were recorded in this study.

Key words

N-fertilizer, rates, placement, wheat

Introduction

In the medium to high rainfall areas of southern Australia there often is a need to apply high rates of N-fertilizer to wheat crops to position the crop for high target yield and/or protein (Angus *et al.* 2001). The use of N-fertilizers as a supplement to soil available N can be a high-risk management tool. Decisions have to be made about application methods, timing, toxicity effects, losses due to volatilisation and low crop N-use efficiency. Toxicity effects and mechanisms associated with medium to high rates of N-fertilizer placed close to the seed are well known (Nyborg *et al*. 1961; Mason and Jarvis 1996). Some growers will apply N-fertilizer in split applications to avoid toxicity, or to manage the canopy structure (Sylvester-Bradley *et al.* 1997). However, many growers prefer applying N-fertilizer in a one-pass operation at sowing using a double-shoot delivery system to separate the seed and fertilizer.

Despite the commercial availability of one-pass seeding systems, there has been little experimental study of the impact of this technology on wheat seedling establishment, vegetative growth and yield when high rates of N-fertilizer are used. Here we report data from field experiments undertaken in South Australia in two seasons (2000 and 2001), where N-fertilizer is applied at seeding with, below or at the side of the seed.

Method

The field experiments with wheat were undertaken at Roseworthy, South Australia (34^{o}32'S, 138^{o}41'E) in 2000 and 2001. The growing season rainfall (Apr-Oct) in these seasons was 345 and 375mm respectively (long-term mean 330mm), and at no stage did the wheat experience moisture stress. The experiments

were in different but nearby fields and the soil were broadly similar (Hypercalcic, Red, Chromosol; Isbell, 1998). The 2000 crop followed a faba bean crop; the 2001 crop followed an oaten hay crop. In both seasons a randomised complete block design with 4 replicates was used, with N-fertilizer rates (0, 33, 66, 99 and 132 kg N/ha) applied using either two (2000) or three (2001) delivery methods. In 2000 N-fertilizer was applied either with the seed or below the seed (50mm deeper); in 2001 an additional delivery method of side application (side banded 50mm) was used. A modified Primary Sales double-shoot system with Harrington knife-points (16mm) spaced at 10″ row spacings (8 rows) was used to sow the wheat (cv. Frame) at 80 kg/ha. Triple superphosphate was pre-drilled at 16 kg P/ha, with N-fertilizer applied as urea. Sowing dates were the 17th (2000) and 29th of May (2001). Crop emergence was assessed (14 days after sowing - DAS) and vegetative growth determined at crop tillering (44 DAS (2000) and 62 DAS (2001)) and close to anthesis (119 DAS (2000) and 140 DAS (2001)). A KEW plot harvester was used to determine grain yield, with sub-samples taken for grain protein and 1000 grain weight. The data were analysed by ANOVA using GENSTAT 6.

Results and discussion

Plant establishment

In both seasons there was a substantial reduction ($P<0.05$) in seedling establishment when N-fertilizer was placed with the seed (Table 1). The high rate of N (132 kg N/ha) with the seed reduced density by 85 and 67% respectively in 2000 and 2001. Mason (1971) has previously shown a 39% reduction in emergence (with 62 kg N/ha), concluding that the reduced emergence was a result of toxic accumulation of free ammonia formed during hydrolysis of urea. Plant density did not increase as the 2000 and 2001 seasons progressed.

In 2001 wheat seedling density was unaffected by high rates of nitrogen (66-132 kg N/ha) when either banded below or to the side of seed (Table 1), with densities of 121 plants/m^2 (below) and 119 plants/m^2 (side) at 132 kg N/ha, which was similar to those treatments that received no added nitrogen. In contrast some reduction in seedling density (27-34%) was recorded when high rates of nitrogen were banded below the seed in 2000, but this was much less compared to the decline in seedling density at the same rates in the with-seed treatments (52-85%). These data show that with the separation of the seed from the fertilizer by 50mm (below or side) has substantially reduced the risk associated with toxicity, but that N-fertilizer, although separated from the seed, can still have a significant influence on seedling emergence.

Dry matter production

In 2000, the N-fertilizer banded below the seed significantly ($P<0.05$) increased dry matter production at the pre-anthesis sampling, and although there was no significant difference (either increased or decreased) due to the N-fertilizer with the seed, the wheat here clearly responded to the N-fertilizer, albeit from a greatly reduced number of plants (Table 1). Dry matter production in 2001 was improved ($P<0.05$) at tillering with banded N-fertilizer, however, by anthesis the difference was no longer evident. Further, the N-fertilizer (2001) with the seed resulted in a large reduction in early plant growth, but this difference was no longer evident at tillering.

Table 1. Effect of nitrogen rate and placement on wheat seedling establishment and vegetative growth in 2000 and 2001 at Roseworthy Campus.

N rate (kg ha^{-1})	Placement	Seedling establishment (plants/m^2)		Dry matter (t/ha)*		
		2000	2001	Tillering	Pre-anthesis	Anthesis

				2000	2001	2000	2001
0	Below	184	104	1.8	3.5	6.7	8.8
	Side		122	-	3.6	-	8.2
	With	150	125	1.7	3.9	4.9	8.6
33	Below	161	112	2.1	5.7	5.6	9
	Side	-	115	-	4.8	-	9.5
	With	109	99	1.6	4.3	5.5	9.5
66	Below	120	129	1.9	4.8	7.7	9.4
	Side	-	146	-	6.0	-	10.5
	With	72	78	0.9	2.9	4.6	9.6
99	Below	118	125	1.4	5.4	13.5	9.9
	Side	-	151	-	5.0	-	10.6
	With	45	51	0.9	3.3	5.5	9.7
132	Below	134	121	1.6	5.1	11.6	11.0
	Side	-	119	-	5.3	-	10.3
	With	23	41	0.4	2.1	4.5	8.6
LSD	(0.05)	30	25	0.6	1.1	0.3	0.8

*Dry matter assessments were undertaken at tillering on 30th June (2000) and 30th July (2001), and pre-anthesis on 4th September (2000) and anthesis 2nd October (2001).

Grain yield, protein and N-content

In 2000, placement of nitrogen had a significant ($P<0.05$) effect on grain yield, with higher grain yield evident when N-fertilizer was banded below, in comparison to with-seed treatments (Table 2). Consistent with the significant decrease in DM yield where N-fertilizer was with the seed, there was a corresponding

large decrease in grain yield with this treatment. Furthermore, grain protein content, whilst high (13-14%), was unaffected by N-fertilizer rate or application method. The consistent values for grain N-content (about 100 kg N/ha) with the banded treatment most likely reflect a relatively high available soil N following the previous seasons bean crop (data not available).

In 2001, banded applications of N-fertilizer resulted in small increases in grain yield ($P<0.05$). In contrast to the results of the previous year, the wheat was able to compensate in growth (anthesis DM, Table 2) and at high rates of N there were only small decreases in grain yield associated with the high rates of N-fertilizer application. The higher rates of N-fertilizer increased ($P<0.05$) grain protein when placed both with the seed and with the banded applications, thus the N-content increased with N applications. There was a low initial soil N (34 kg N/ha) at this site.

These data highlight the risk producers have with using high rates of N, both with management choice and potential outcomes. In 2000, although there was high crop uptake of N with N-fertilizer (DM yield responses; high grain N content values), there was no resulting grain yield or protein benefit. In the 2001 season, there were grain yield and protein responses, however, it is unlikely if any economic benefits would result from the high rates of N-fertilizer used.

Table 2. Effect of nitrogen rate and placement on mean grain yield, protein and N-content in 2000 and 2001 at Roseworthy Campus.

N rate (kg ha^{-1})	Placement	Grain yield (t/ha)		Grain protein (%)		N-content (kg N/ha)	
		2000	2001	2000	2001	2000	2001
0	Below	4.39	3.33	13.1	8.1	100.5	47.2
	Side	-	3.48	-	7.9	-	48.0
	With	4.31	3.39	13.4	7.9	101.3	46.6
33	Below	4.54	3.74	13.5	8.2	107.1	53.7
	Side	-	3.67	-	8.3	-	53.3
	With	3.99	3.62	13.5	8.3	94.3	52.3
66	Below	4.52	3.75	13.4	8.7	106.2	56.8
	Side	-	3.68	-	8.5	-	54.7
	With	3.70	3.59	13.6	9.1	87.8	57.2
99	Below	4.18	3.81	13.8	8.9	100.5	59.3

	Side	-	3.88	-	8.8	-	59.7
	With	3.65	3.64	13.3	9.4	84.7	59.6
132	Below	4.01	3.66	13.6	8.5	95.3	54.1
	Side	-	3.72	-	9.3	-	60.5
	With	2.98	3.36	14.0	10.6	73.1	62
LSD	(0.05)	0.54	0.18	0.1	0.5		

Conclusion

Banding applications of nitrogen either below or to the side of the seed can provide adequate separation between seed and fertiliser avoiding toxicity to wheat, although some risk remains. However, these data highlight that for improvements in N-use efficiency, a more strategic approach to N supply should be considered, rather than just relying on a one-off large application at sowing.

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