Improving nitrogen fertiliser use efficiency in wheat using mid-row banding

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Key findings

- Nitrogen offtake in grain was higher with mid-row banding urea than urea broadcast and incorporated by sowing for both Beckom⁽ᵗʰ⁾ and LongReach Spitfire⁽ᵗʰ⁾ at the 80, 120 and 160 rates of N application.
- Apparent fertiliser recovery in grain was also higher from mid-row banding urea than from urea broadcast and incorporated by sowing in five of the possible eight treatment comparisons.
- Soils cored at stem elongation from the mid-row banding treatment showed higher ammonium levels in the top 20 cm and lower nitrate concentration at 60–100 cm than urea broadcast and incorporated by sowing.
- Roots proliferated around and below the original mid-row banding. These results indicate potential for mid-row banding to improve N use efficiency.

Introduction

Fertiliser costs represent a significant component of variable costs for growing grain crops and are estimated to represent 15–20% of all cash costs and 20–25% of variable costs. The high cost of fertiliser has caused grain growers to focus on nutrient management in an attempt to control input costs and reduce financial risk. Typically, nitrogen (N) fertiliser is applied to wheat at sowing (e.g. mono-ammonium phosphate – MAP and di-ammonium phosphate – DAP) and again in the vegetative phase around stem elongation as urea. The in-crop efficiencies of fertiliser N retrieval vary greatly, with approximately 44% in above-ground plant parts, 34% in soil, and 22% not recovered (Pilbeam 1996). Increases in the efficiency with which wheat extracts fertiliser N from the soil can result in significant fertiliser savings. In this experiment, we compare three methods of N supply to wheat:

1. surface spread in front of the seeder (early May)
2. mid-row banding at sowing (early May)
3. surface spread at stem elongation (late July).

The difference method was used to evaluated the efficiency of each.

Site details

Location	Wagga Wagga Agricultural Institute, Wagga Wagga
Soil type	Red chromosol, pH_{Ca} 5.1 in the 0–10 cm layer with a starting N content of 142 kg/ha down to 150 cm, measured on 4 May 2016
Experimental design	Randomised complete block design with six rates of N used in each of three methods of N application, all of which were tested on two varieties of wheat in a four-replicate experiment (Table 1)
Stubble management	Experiment was direct drilled into light 1.0 t/ha canola stubble on 5 May 2016
Fertiliser	At sowing phosphorus (P) as triple super was drilled 50 mm below seed at a rate of 25 kg P/ha
Sowing date	5 May 2016
Plant population	The mean plant density achieved was 125 plants/m² counted at DC14 There were no significant treatment effects on plant density
Sowing	The experiment was direct drilled with DBS tynes spaced at 240 mm

Weed management	Weed management included glyphosate (450 g/L) at 1.2 L/ha plus 2,4-D (625 g/L) at 320 mL/ha during the fallow period (January–April 2016) Weed control was undertaken by applying the pre-emergent Sakura® (pyroxasulfone 850 g/L) at 118 g/ha and Logran® (triasulfuron 750 g/L) at 35 g/ha on 4 May 2016 and was incorporated at sowing
Insect management	Aphids were controlled at late stem elongation by applying Aphidex® (Pirimicarb 500 g/kg) at 250 g/ha
Disease management	Precautionary disease control was implemented. Seed was treated with Hombre® Ultra (imidacloprid 360 g/L and tebuconazole 12.5 g/L) at 200 mL/100 kg. Prosaro® (prothioconazole 210 g/L and tebuconazole 210 g/L) was 300 mL/ha at DC 30 and 37 to prevent and/or supress rust infections.
Harvest date	15 December 2016
Rainfall	A total of 587 mm rainfall was recorded at the experiment site during 2016. The growing season rainfall (GSR) was 368 mm.

Treatments

Table 1. Varieties, N rates and N application methods.

Variety	N rate (kg/ha)	N application method
Beckom⟬	0	Banding: mid-row banding (4 May)
LongReach Spitfire⟬	25	PreSowing: spread pre-sowing (4 May)
	50	DC30: spread at growth stage DC30 (14 July)
	80	
	120	
	160	

Note: All nitrogen applied as urea.

Measurements

Nitrogen take-off

Nitrogen take-off was estimated by protein (%) ÷ 5.7 (conversion constant) × grain yield (t/ha).

Nitrogen fertiliser use efficiency (NUE)

NUE is estimated by (N take-off from plots where N is applied) minus (N take-off from plots where no N applied), divided by rate of N fertiliser added.

Seed measurements

Grain protein and grain seed quality were estimated using NIR (Foss Infratec 1241 Grain Analyzer) and seed imaging (SeedCount SC5000R) respectively.

Economic returns

Economic returns after N costs were calculated using 2017 prices × grain yield (t/ha) at the plot level. Grain value per tonne was either $160 (ASW1, <10.5% protein), $181 (APW1 >10.5% protein), $209 (H2 >11% protein) or $243 (APH2 >13% protein). Test weight, screenings and stained grain were within grain category standards so were not included in the calculations. Cost of N was assumed to be $1/kg of N (i.e. $460/tonne of urea at 46% N).

Results

Nitrogen use efficiency

Nitrogen take-off in grain was used as an estimate of NUE. Applying N at sowing using mid-row banding and surface spreading N at stem elongation (DC30) had higher N take-off than N spread and incorporated at sowing (Table 2). This efficiency difference was evident across most N rates from 50 kg N/ha to 160 kg N/ha and occurred even when different N partitioning (yield verses protein) was evident between the two wheat varieties (Beckom⟬ – high yields

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verse LongReach Spitfire⊕ – high protein). The highest N take-off occurred at 160 kg N/ha, while the highest grain yields were achieved at 120 kg N/ha.

Economic returns after considering N costs, wheat variety, grain protein, screenings, test weight and stained grain are estimated for Beckom⊕ and LongReach Spitfire⊕ respectively. Returns for Beckom⊕ were highest in the N banding treatment at 80 kg N/ha ($1,409), while the highest return for the DC30 and pre-sowing treatments occurred at 120 kg N/ha ($1,397 and $1,343 respectively). Returns for LongReach Spitfire⊕ were highest in the N banding treatment at 120 kg N/ha ($1,420) and highest for the DC30 and pre-sowing treatments at 160 kg N/ha ($1,347 and $1,305 respectively). Mid-row banding was more profitable for LongReach Spitfire⊕ with 120 kg N/ha of banded compared to other methods and rates of N application.

Table 2. Grain yield (t/ha), protein (%), N take-off (kg N/ha) and net return after N costs for Beckom⊕ and LongReach Spitfire⊕ calculated at the plot level.

Treatment	Beckom⊕				LongReach Spitfire⊕			
	Grain yield (t/ha)	Protein (%)	N take-off (kg/ha)	Net after N costs ($/ha)*	Grain yield (t/ha)	Protein (%)	N take-off (kg/ha)	Net after N costs ($/ha)*
nil_0	5.9	10.5	110.9	1,019	5.2	10.6	97.0	891
seed_25	6.2	10.3	111.7	1,030	5.6	10.8	106.0	955
Banding_50	6.8	11.3	133.7	1,201	5.7	12.9	130.2	1,247
Banding_80	7.1	12.0	150.2	**1,409**	6.0	13.5	141.4	1,322
Banding_120	**7.3**	12.2	155.7	1,399	**6.3**	13.9	154.8	**1,420**
Banding_160	**7.3**	**12.7**	**161.9**	1,360	6.2	**14.6**	**159.2**	1,355
DC30_50	6.8	11.0	132.2	1,248	5.6	12.5	123.9	1,174
DC30_80	7.0	11.5	142.4	1,340	5.9	13.2	136.8	1,253
DC30_120	**7.3**	12.4	157.2	**1,397**	**6.2**	13.2	144.8	1,292
DC30_160	**7.3**	**12.7**	**161.9**	1,363	**6.2**	**14.5**	**157.2**	**1,347**
PreSowing_50	6.6	10.5	122.2	1,079	5.7	12.6	125.4	1,147
PreSowing_80	6.9	11.3	137.8	1,225	5.7	12.6	127.0	1,166
PreSowing_120	**7.2**	11.8	147.7	**1,343**	**6.1**	12.9	137.9	1,252
PreSowing_160	7.1	**12.1**	**151.6**	1,333	6.0	**13.4**	**141.7**	**1,305**
l.s.d. $P = 0.05$	0.3	0.90	7.6	114	0.3	0.92	7.6	114

Note: Bold indicates the highest value within each nitrogen treatment.

* Economic returns after N costs are based on: $1/kg of N; and wheat price $160/t (ASW1), $181/t (APW1 >10.5% protein), $209/t (H2 >11% protein), $243/t (APH2 >13% protein).

Nitrogen profiles

Figure 1 shows soil nitrogen in samples taken from plots sown to Beckom⊕ with 160 kg N/ha applied. N applied pre-sowing and measured at DC31 was converted to nitrate and leached down the soil profile to a depth of 60–100 cm (Figure 1a). The mid-row band method of N application had large amounts of N present as ammonium in the 10–20 cm layer (Figure 1b), which did not leach below the coring depth even under very wet conditions conducive to leaching. N applied to the soil surface at DC30 (14 July) and measured at DC31 (29 July) was largely in the ammonium form in the 0–10 cm layer (Figure 1c).

Nitrogen recovery

The proportion of apparent fertiliser N recovery in grain was higher for LongReach Spitfire⊕ than Beckom⊕. There was also a tendency for the proportion of apparent fertiliser N recovery in grain to be higher in mid-row banding compared with the pre-sowing method of N application; although this did not occur at all N rates (Figure 2).

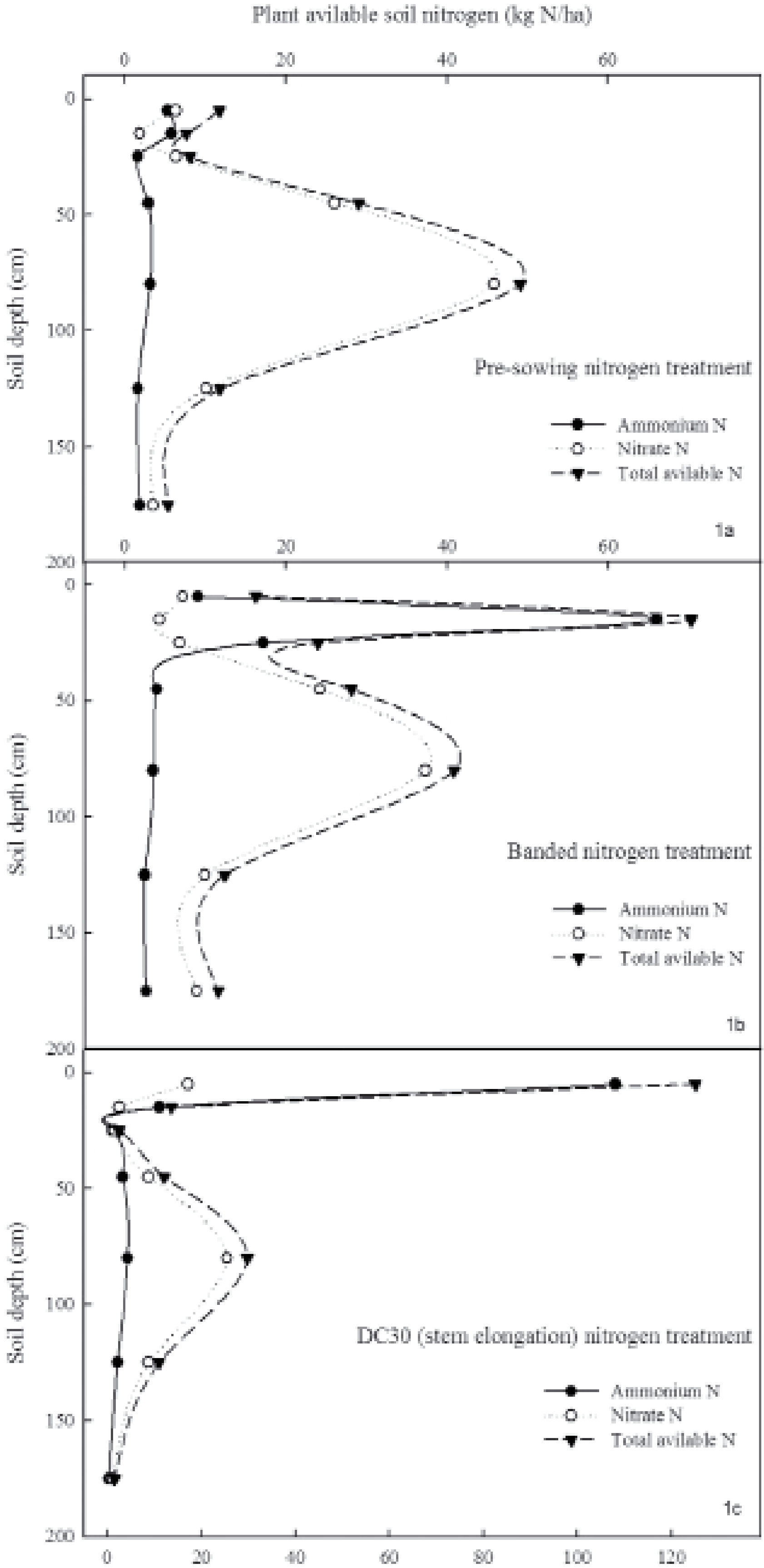

Figure 1. Soil nitrate (dotted line, open circle), ammonium (solid line, closed circle) and total soil available N (dashed line, closed triangle), (kg/ha) measured at DC31 (last week of July) from plots sown to Beckom[Φ] with 160 kg N/ha applied as spread pre-sowing, mid-row banded or spread at DC30. Soil measurement depths were 0–10 cm, 10–20 cm, 20–30 cm, 30–60 cm, 60–100 cm, 100–150 cm and 150–200 cm. For graphing purposes, the soil depth data is presented at the following depths 5 cm, 15 cm, 25 cm, 40 cm, 80 cm, 125 cm and 175 cm. Topdressing of urea at DC30 occurred 15 days before soil coring.

Root proliferation

Root length (cm) next to banded urea was measured in the 160 kg N/ha treatments at anthesis on variety Beckom⁽ᵗʰ⁾, by taking soil cores 6 cm away from the crop row and 6 cm away from the mid-row band (Table 3). Total root length in the 10–20 cm layer was significantly (P = 0.05) higher for the mid-row banding N treatment than for the other treatments. Total root length in the pre-sowing N treatment was significantly higher than the other treatments in the 60–100 cm layer. Root length proliferation in nutrient-rich sections of the soil has been shown in other species to significantly increase the efficiency of nutrient retrieval and is a promising feature of this research.

Table 3. Root length (cm) of variety Beckom at anthesis measured in the 160 kg N/ha treatments for depths 0–10 cm, 10–20 cm, 20–30 cm, 30–60 cm, 60–100 cm and 100–150 cm.

Treatment	Depth (cm)						
	0–10	10–20	20–30	30–60	60–100	100–150	Total
nil_0	2247	204	148	771	1035	65	4470
Banding_160	2375	1126	373	901	1436	49	6260
DC30_160	2160	510	210	755	1243	35	4913
PreSowing_160	1427	546	218	860	1716	70	4837
l.s.d. (P = 0.05) = 341							

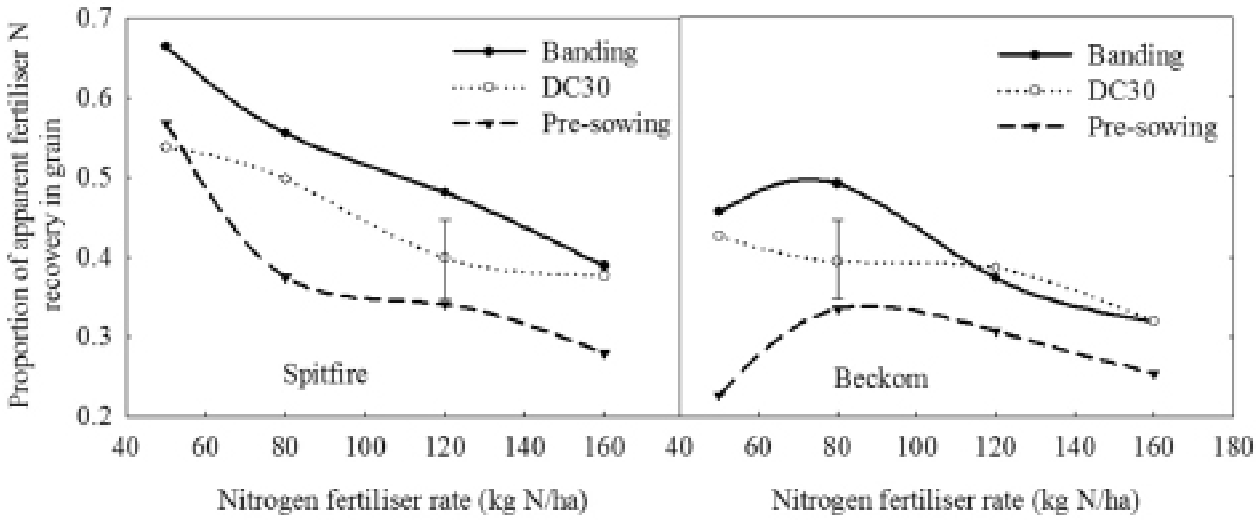

Figure 2. Apparent fertiliser-N recovery in grain for varieties Spitfire and Beckom in relation to three methods of N application and four N rates.

Summary

Mid-row banding of N shows promise as a strategy to improve N-use efficiency in wheat. This work has shown that banding urea creates an ammonium tube in the soil that is not readily leached. It also shows that wheat can proliferate root length around the ammonium band (Table 3), which has been shown to increase nutrient use efficiency in other species. The highest N removal rates were achieved by banding; the most profitable rate of applied N was lower for banded N fertiliser than for applied N from other application methods.

Reference

Pilbeam CJ (1996). Effect of climate on the recovery in crop and soil of 15N-labelled fertilizer applied to soil. *Fertilizer Research*. Vol 45: 209–215.

Acknowledgements

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