Mid-row banding urea: effect on NUE and productivity in wheat and canola

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Abstract
Nitrogen (N) fertiliser is a key input to modern Australian cropping systems, however the efficiency with which it is utilised by crops varies significantly; in part due to competition from loss and immobilisation mechanisms. One option to address this is the use of mid-row banding (MRB), where N is applied in concentrated bands between every second pair of crop rows, potentially reducing N loss and slowing crop access to applied N thereby improving nitrogen use efficiency (NUE) and productivity. In 2018 two field trials were established in Victoria to assess the utility of mid-row banding N to wheat and canola at sowing compared with other methods including banding below the seed and surface application post sowing. Nitrogen was applied as urea either in solution or granular at rates of 25 and 50kg N/ha. Banding N either below the seed or mid-row increased grain yield of wheat (9 to 16%) and canola (2 to 7%) compared with surface application. This was associated with significant increases in crop recovery of fertiliser N, and reduced fertiliser loss (up to 40%). Mid-row banding also showed potential to increase grain protein (2 to 7%) in wheat compared with all other methods of application. These results suggest that applying N fertiliser by mid-row banding may have scope for improving NUE of dryland crops in similar environments.

Key Words
fertiliser placement, top-dressing, deep banding, ultra-high-pressure injection, ^{15}N mass balance

Introduction
Nitrogen fertiliser application is the single largest variable cost to the Australian grains industry. However, less than half of the N applied is accessed by the crop in the year of application and on average 22% of applied N is lost to the environment (Angus and Grace 2017). Furthermore, sub-optimal N fertilisation is a major contributor to the gap between water-limited potential and actual wheat yields (Hochman and Horan 2018); consequently practices to improve NUE are needed. One option to reduce N loss and improve crop NUE is to apply N by mid-row banding where N fertiliser is applied between every second pair of crop rows (Campbell et al. 1990, Sandral et al. 2017).

By applying N fertiliser such as urea below the soil surface, it is possible to reduce loss due to ammonia volatilisation (Rochette et al. 2013). Moreover, concentrated bands of ammonium N can slow nitrification and immobilisation and encourage root proliferation in the region of the fertiliser band (Passioura and Wetselaar 1972), potentially reducing denitrification and leaching and improving crop access to applied N. One limitation to application by mid-row banding is the ability of conventional soil openers to place N mid-row under narrow row-spacings where previous crop residues are retained. However, recent developments in the use of ultra-high-pressure injection as a 'liquid coulter' present the opportunity to cut through residues and inject N fertiliser into the soil under such scenarios. Two experiments were conducted in 2018 to test whether applying N fertiliser by mid-row banding at sowing increases NUE in wheat and canola compared with other methods.

Methods
In 2018, two field trials were established in Victoria to assess the effect of method of N fertiliser (urea) placement on grain yield, quality and NUE. The first trial was sown to wheat (*cv.* Kord Cl Plus) at Ouyen on a deep sand with low levels of total carbon and N and organic carbon (0.8%, 0.06% and 0.5% respectively at 0-10cm). The second trial was sown to canola (*cv.* 44Y90 CL) at Longerenong on a grey clay, also with low levels of total carbon and nitrogen and organic carbon (1.7%, 0.15% and 1.1% respectively at 0-10cm). Both sites are characterised by a semi-arid climate; mean annual and

growing season (April-October) rainfall is 306mm and 194mm at Ouyen and 417mm and 279mm at Longerenong, respectively.

The experiments were a complete randomised block design replicated four times, testing a factorial combination of five methods of fertiliser application (mid-row banding, top-dressing after sowing, banding 25mm below the seed, streaming nozzle application after sowing and ultra-high-pressure injection in a mid-row configuration) and two rates of N (25 and 50 kg N/ha applied as urea). Additional rates of N (15 and 100kg N/ha) were also applied at sowing either banded below the seed (Ouyen) or top-dressed (Longerenong) to establish the N limited yield potential at each site. Urea was applied in granular form when top-dressed and as an aqueous solution (Yara, N24) for the streaming nozzle and ultra-high-pressure injection treatments. Banded treatments were applied as both granular and aqueous solutions to allow comparison between products. Mid-row banding required a purpose-built machine using twin disc openers to place N fertiliser at a depth of 35mm. Ultra-high-pressure injection was completed using an Aqua-Till® liquid coulter producing pressures of *ca.* 55,000 psi (SANTFA, Berri, South Australia and Flowcorp, Kent, Washington, USA). Unfertilised controls with and without mid-row banding were also included and plot size was 1.8m × 10m.

At Ouyen, fertiliser application and sowing was undertaken on 17 and 18 May, while at Longerenong it was undertaken on 18 and 19 May. All plots received a basal application of phosphorus fertiliser (Granulock® Z, 11:21.8:4:1, N:P:S:Zn, Incitec Pivot) at 60 kg/ha banded with the seed. Chemical inputs were managed according to best practice to keep the trials free from weeds, pests and diseases. To avoid crop failure due to dry seasonal conditions, both sites were irrigated twice between 7 September and 5 October (coinciding with pre-flowering to early grain filling) with approximately 20mm applied on each occasion. Trials were machine harvested on 4 December (Ouyen) and 26 November (Longerenong) with both sites being direct headed.

Nitrogen use efficiency was measured using a ^{15}N mass balance approach for a subset of treatments including: urea banded below the seed and applied using streaming nozzles at 50 kg N/ha and mid-row banded at both 25 and 50 kg N/ha. Steel micro-plots (60 × 30 cm) were inserted into the unfertilised buffer at the end of each plot to a depth of 20 cm and ^{15}N enriched (10% a.e.) urea was applied in solution after sowing according to treatment. Micro-plots were harvested at maturity and dried at 70°C before threshing and fine grinding. Soil from within each micro-plot was completely excavated at depths of 0-10 and 10-20 cm and dried at 40°C prior to fine grinding and analysis of total N and $\delta^{15}N$ by IRMS. Fertiliser recovery was calculated using the approach of Malhi et al. (2004) and all data were analysed using ANOVA.

Results

There was a strong response to N fertiliser application at both sites despite dry seasonal conditions; April to October rainfall was 102mm at Ouyen and 187mm at Longerenong. At both sites 73kg of mineral N was available to a depth of 1.2m at sowing. At Ouyen, the addition of a further 50kg N/ha increased wheat yield from 1.3 to 1.9t/ha and significantly increased grain protein from 9 to 11% (Table 1). Adding 100kg N/ha below the seed resulted in significant reductions in plant establishment due to insufficient separation between seed and fertiliser, reducing yield by 0.3t/ha compared to a rate of 50kg N/ha. At Longerenong, canola yield increased significantly up to a rate of 100kg N/ha (top-dressed) reaching 1.3t/ha compared with 1.0t/ha where no additional N was applied. However, there was no effect of N addition on canola oil content. At both sites, a significant number of frosts were observed during September (8 at Ouyen and 11 at Longerenong), coinciding with key reproductive stages and likely to have decreased yield potential.

Application method had a significant ($P<0.05$) effect on grain yield (Ouyen and Longerenong) and grain protein (Ouyen, Table 2). Banding N fertiliser either below the seed or mid-row resulted in the highest mean yield. At Ouyen this was significantly higher (15 to 16%) than where N was applied using a streaming nozzle, while at Longerenong, this was significantly higher (6 to 7%) than where N was top-dressed. At Ouyen, mid-row banding N significantly increased grain protein (2 to 7%)

compared with all other methods indicating that mid-row banding may have delayed crop access to applied N due to greater physical separation between the crop and fertiliser. Previous studies have highlighted the potential to increase grain protein with delayed crop access to applied N, although this has often been associated with reduced yield response (Fischer et al. 1993) which is unlike the current study. At Longerenong there was no effect of application method on grain oil content. Across both sites, the form of urea applied had no significant effect on grain yield, protein or oil (data not shown).

Table 1. Grain yield and protein/ oil response to N rate banded as urea below the seed (Ouyen, wheat) or top-dressed after sowing (Longerenong, canola) in 2018. Superscripts indicate significant differences (*P*<0.05); treatments followed by the same letter within a given site are not statistically different.

N rate (kg/ha)	Ouyen		Longerenong	
	Grain yield (kg/ha)	Grain protein (%)	Grain yield (kg/ha)	Grain oil (%)
0	1274^{b}	9.3^{c}	1035^{c}	36.8^{b}
15	1507^{b}	10.0^{c}	1094^{bc}	37.9^{a}
25	1816^{a}	9.9^{c}	1153^{b}	38.0^{a}
50	1892^{a}	11.0^{b}	1175^{b}	36.0^{bc}
100	1571^{ab}	13.0^{a}	1296^{a}	35.5^{c}
LSD (P<0.05)	346	1.0	102	0.85

Table 2. Grain yield and protein/ oil response to method of N application at sowing at Ouyen (wheat) and Longerenong (canola) in 2018. Values represent the mean of 25 and 50kg N/ha rates, superscripts indicate significant differences (*P*<0.05); treatments followed by the same letter are not statistically different.

Application method	Ouyen		Longerenong	
	Grain yield (kg/ha)	Grain protein (%)	Grain yield (kg/ha)	Grain oil (%)
Ultra-high-pressure injection	1746^{ab}	10.8^{ab}	1200^{ab}	36.7
Banded below the seed	1854^{a}	10.4^{b}	1226^{a}	36.8
Mid-row banded	1870^{a}	11.0^{a}	1240^{a}	36.6
Streaming nozzle	1614^{b}	10.4^{b}	1203^{ab}	36.4
Top-dressed	1705^{ab}	10.3^{b}	1162^{b}	37.0
LSD (P<0.05)	196	0.6	44	n.s.

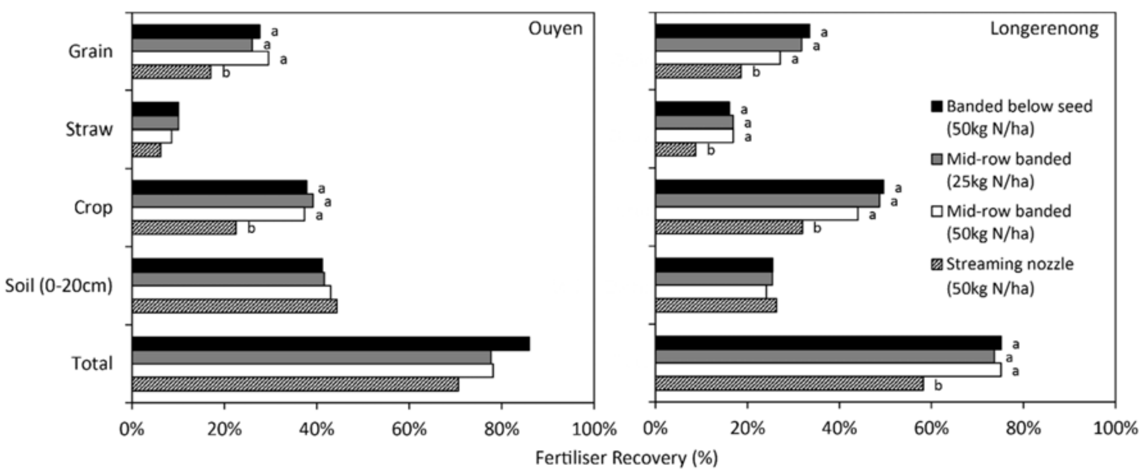

Figure 1. Effect of application method on recovery of fertiliser N at harvest in above ground biomass and its components, soil to a depth of 20cm and in total (sum of soil and crop) for wheat grown at Ouyen and canola grown at Longerenong in 2018. Superscripts indicate significant differences (*P*<0.05); treatments followed by the same letter within a given site are not statistically different.

Nitrogen use efficiency, measured by recovery of fertiliser N in above-ground biomass at harvest, significantly increased where N was banded either below the seed or mid-row compared to streaming application (Figure 1). Crop recovery of applied N ranged from 22 to 39% at Ouyen and 32 to 50% at Longerenong and increases were primarily associated with increased N recovery in the grain. At Ouyen, a larger proportion of the applied N was recovered in the soil to a depth of 20cm (43 and 25%

respectively) reflecting differences in soil N reserves and the potential for greater immobilisation given similar levels of cereal residue at each site. Nonetheless, at both sites, the effect of application method on recovery of applied N in the soil was limited. Total recovery of applied N (in both crop and soil) ranged from 60 to 80% across both sites and at Longerenong banded application resulted in a significant increase in total recovery. At Ouyen this effect was not significant, however a similar trend was observed. Given that rainfall following sowing was limited at both sites (daily totals <1.5mm up to 10 days post sowing) this observation may be related to increases in ammonia volatilisation due to surface application (Rochette et al. 2013).

Conclusion

Applying N fertiliser by mid-row banding at sowing has the potential to increase grain yield of both wheat and canola compared to surface application. This was related to increased uptake of fertiliser N and potential reductions in N loss. However mid-row banding showed limited yield benefit when compared with the standard practice of banding N below the seed. Mid-row banding did however significantly increase grain protein in wheat compared with all other methods of application. Furthermore, where high rates of N are required at sowing, mid-row banding offers the benefit of greater seed-fertiliser separation, eliminating the risk of fertiliser toxicity. Ultra-high-pressure injection may present an opportunity to mid-row band fertiliser under high stubble loads, although on average it did not result in as high a yield or protein (wheat) as a disc opener in this evaluation.

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