N Mid-row Banding in a Post-rice Crop

REF: 9175353

Leigh Vial[1], Laura Kaylock[2] and James Brinkoff[3]
[1]Moulamein irrigation farmer and Deakin University, Hanwood
[2]Project officer, Western Murray Land Improvement Group, Barham
[3]Research Scientist Centre for Regional and Rural Futures, Deakin University, Geelong

Grains Development Research Corporation 2018

Contents

1. Abstract

Irrigated cropping on clay Sodosols in the Riverina is subject to frequent waterlogging during winter, especially in the case of wheat following rice. Past experiments have alluded to improved nitrogen recovery when urea was placed in a concentrated mid-row band at sowing. However, little research has involved measuring the stability of banded nitrogen when waterlogged.
In this experiment mid-row banding (MRB) was compared with topdressed nitrogen practices using 150kg.N.ha^{-1} in both waterlogged and non-waterlogged conditions. For the MRB treatments, during sowing seed was blocked off in every third row and urea (46%) was banded as mid-row fertiliser. Topdressing treatments were applied between DC31-32, 150NTE before the waterlogging event and 150NTL prior to a small rainfall event. A large portion of the banded nitrogen was preserved during the waterlogging event but only 5-8% remained 131 DAS. Consequently the MRB treatments had more grain yield than 15N, similar to 150NTL but less grain yield than 150NTE. In the waterlogged treatments ANRE was between 18-22% for MRB treatments and 21-36% for topdressed treatments, with 150NTE being the most efficient. The waterlogging event affected all treatments, such that both CCCI and NDRE were similar for all treatments immediately after the water-logging event. The topdressed treatments recovered better after the waterlogging event than the MRB treatments. MRB showed an acceptable response in both waterlogged and non-waterlogged conditions, but similar or less than N topdressing treatments.

2. Key Words

Mid-row banding, nitrogen fertiliser, irrigation, cropping Riverina

3. Introduction

Irrigated winter crops in the Riverina need substantial nitrogen (N) supply for high, water productive yields. A 5t. ha^{-1} wheat crop needs a supply of 240kg. ha^{-1} . For continuous cropping systems, often more than 150kgN. ha^{-1} of that must come from fertilizer nitrogen (N).

With an increasing incidence of dry winters in the Riverina, top-dressed N can be lost via volatilisation or may not be washed into the active root zone of the plant. More than 15mm is required to move nitrogen into the root zone of plants (Armstrong, 2016). On average 10-20% of Urea N is lost when surface applied (Irvine et al., 2010). These losses can be exacerbated in an irrigated scenario with high crop residues containing the urease enzyme, speeding up urea hydrolysis and preventing N from reaching the soil (Jones et al., 2007).

In wet winters the saturated soil profile of a pre-watered or rice stubble crop increases the risk of prolonged periods of waterlogging in winter from relatively modest rainfall events. When N is in the nitrate form it can quickly be leached below the root zone or denitrified as nitrous oxide gas, resulting in a large loss of fertiliser N (Zerulla et al., 2001). Denitrification is particularly a risk on clay soils in the Riverina, where soil internal drainage rates are low. As such, waterlogging will be a strong focus of this trial.

Placing fertiliser into a concentrated mid-row band at sowing can offer a low risk alternative for meeting the crops N requirements. Much of the nitrogen can be preserved in the ammonium form, as nitrification is inhibited when ammonium concentration reaches 3000 ppm or when the soil pH >8 (Wetselaar et al., 1973). Angus et al. (2014) found that high concentrations of banded N were toxic to microbes responsible for nitrification. Brar (2013) recorded that banding also resulted in a corresponding increase in soil pH, further inhibiting nitrification. As a result, banding should provide a slow-release of N throughout the growing season. Losses via volatilisation, leaching and denitrification will potentially be minimised as urea will be preserved in the ammonium form which is not vulnerable to these losses. In addition, roots have been shown to enclose the band of fertiliser, making them well-placed to intercept mobile nitrate once available (Wetselaar et al., 1972; Angus et al., 2014; Sandral et al., 2017).

Hence, mid-row banding should be able to reliably supply high rates of N, without the need of the extra time and expense to topdress, in a wide range of seasonal conditions. Previous trial work in 2015 and 2016 rice stubbles subjected to winter waterlogging,showed that the banded N supplied nutrition to until flowering. This is supported by the work of Tsai et al. (1992) who suggested that due to lower losses, ammonium in the soil should be available for late-season uptake.

How much of the applied mid-row N is preserved from water-logging, and how does it compare to topdressing?

This trial aimed to test MRB in the presence and absence of waterlogging. It was intended to trial in a rice stubble (high water-limited yield, very low N status), but heavy early rain forced a change to a barley stubble that had not been pre-watered, to ensure successful sowing and differentiation between the waterlogging treatments.

4. Methodology

3.1 Nitrogen treatments

During sowing seed was blocked in every third row and urea (46%) was banded as mid-row fertiliser.
15N: MAP + 1.0% Zn @ 150 kg/ha in the seed row
150N TE (topdressed early): MAP + 1.0% Zn @ 150 kg/ha in the seed row + 290 kg/ha Urea spread before the waterlogging event
150N TL (topdressed late): MAP + 1.0% Zn @ 150 kg/ha in the seed row + 290 kg/ha Urea spread after the waterlogging event
150N MRB (mid-row banded): MAP + 1.0% Zn @ 150 kg/ha in the seed row + 290 kg/ha Urea banded in the mid-row
104N MRB (mid-row banded): MAP + 1.0% Zn @ 150 kg/ha in the seed row + 190 kg/ha Urea banded in the mid-row

3.2 Waterlogging treatments

Dry: No waterlogging event imposed
Wet: A waterlogging event imposed, by irrigating on July 29th, then draining on August 9th after redox potential had dropped below -350 mV at pH 4.7.

3.3 Plot design

A split plot design, with waterlogging treatments in the main plots, and nitrogen treatments in the sub-plots. There were four replicates. Each plot will be approximately 40 m long and 8 m wide.

3.4 Plant measurements

- Plant number
- Tiller number
- Head number
- Grain yield
- Grain protein
- 1000-grain weight
- SPAD meter measurements (July 13th, July 28th, August 16th and September 29th)
- NDVI/Red Edge (July 2nd, August 14th and September 26th)

3.5 Soil measurements

- Soil test pre-sowing
    - One sample (0-10cm), 12 sample points testing for complete soil nutrition
    - One sample (0-60cm), 12 sample points testing for ammonium, nitrate and total N only.
- Mid-row band N test (ammonium and nitrate), 5-15cm deep (June 19th, July 28th, August 23rd, September 29th and Feb 17th)
    - 24 samples (4 replicates, 104N MRB, 150N MRB and a control, both Wet and Dry)
- Soil matric potential daily (from June 19th to Sept 26th)
- Soil redox status daily (from June 19th to Sept 26th)

3.6 Management

The trial was conducted in a rice bay that was cropped with a 5 t/ha barley crop in 2016, but not pre-watered. Due to 50-70 mm of rain on April 20th, the intended rice stubble had standing water. This made seeding difficult, levee construction even more difficult and made it exceedingly likely that the entire site will be waterlogged during the season, rendering the 'Wet' treatment redundant.

The site had barley stubble. It was sprayed with glyphosate 450 @ 1.6 L/ha plus Nail at 30 mL/ha and LI700 @ 350mL/100L, then seeded with a Bettinson disc drill, at 18 cm spacing. Every third row was blocked to seed and Granulock, and only urea will be placed in this row (at about 7 cm depth) for the 104N MRB and 150N MRB treatments. Nothing was placed in it for the other treatments. Mace wheat was sown on the 16th of May at 85 kg/ha (at 3-5 cm depth), with 150 kg/ha MAP + 1.0% Zn (treated with Impact at 4 L/t for fungal suppression).

The early topdressing treatment was applied at GS31 on the 28th of July, immediately prior to the waterlogging treatments were applied on the 29th of July. The late topdressing treatment was applied between GS32-33 on the 16th of August prior to a small rainfall event.

Axial @ 300mL/ha plus Agidor @ 500mL/100L, a selective herbicide for grass weeds, was applied on July 10th. Insect control was provided using Dominex Duo @ 125mL/ha to control blue-green aphids and a later application (July 19th) of Chlorpyrifos @ 1.2L/ha to control Russian Wheat Aphids. Zinc phosphide mouse bait was spread twice during the season.

The site was not pre-watered. Levees were constructed after sowing, to exclude water from the 'Dry' plots during the winter waterlogging event. Waterlogged treatments were irrigated on the 29th of July for 10 days. Two spring irrigations occurred on the 19th of September and 20th of October to ensure the crop reached the nominated yield potential of 5t/ha.

5. Results and discussion

Yields of all treatments were modest, driven primarily by a small number of grains per head. This is not surprising, as neither the dry nor wet irrigation treatments had even near-ideal conditions. The dry treatment would have suffered from substantial water stress by the first irrigation on September 19th as the field was not pre-irrigated. The wet treatment was exposed to 10 days' inundation beginning July 29th.

A large proportion of the mid-row banded N was preserved as ammonium through the waterlogging event, even though almost all nitrate was denitrified (Figure 1). About half of the initial concentration was still present at 91 DAS after the waterlogging event, but only 5-8% of the mid-row banded N was available on October 3rd, 131 DAS, so the bulk of it was exhausted by flowering in late-September, when the number of grains per head would still have been being determined.

The mid-row ammonium concentration reduced a similar amount from before to after the waterlogging event, for both the water-logged and unwater-logged treatment, suggesting that little or no ammonium was lost due to waterlogging.

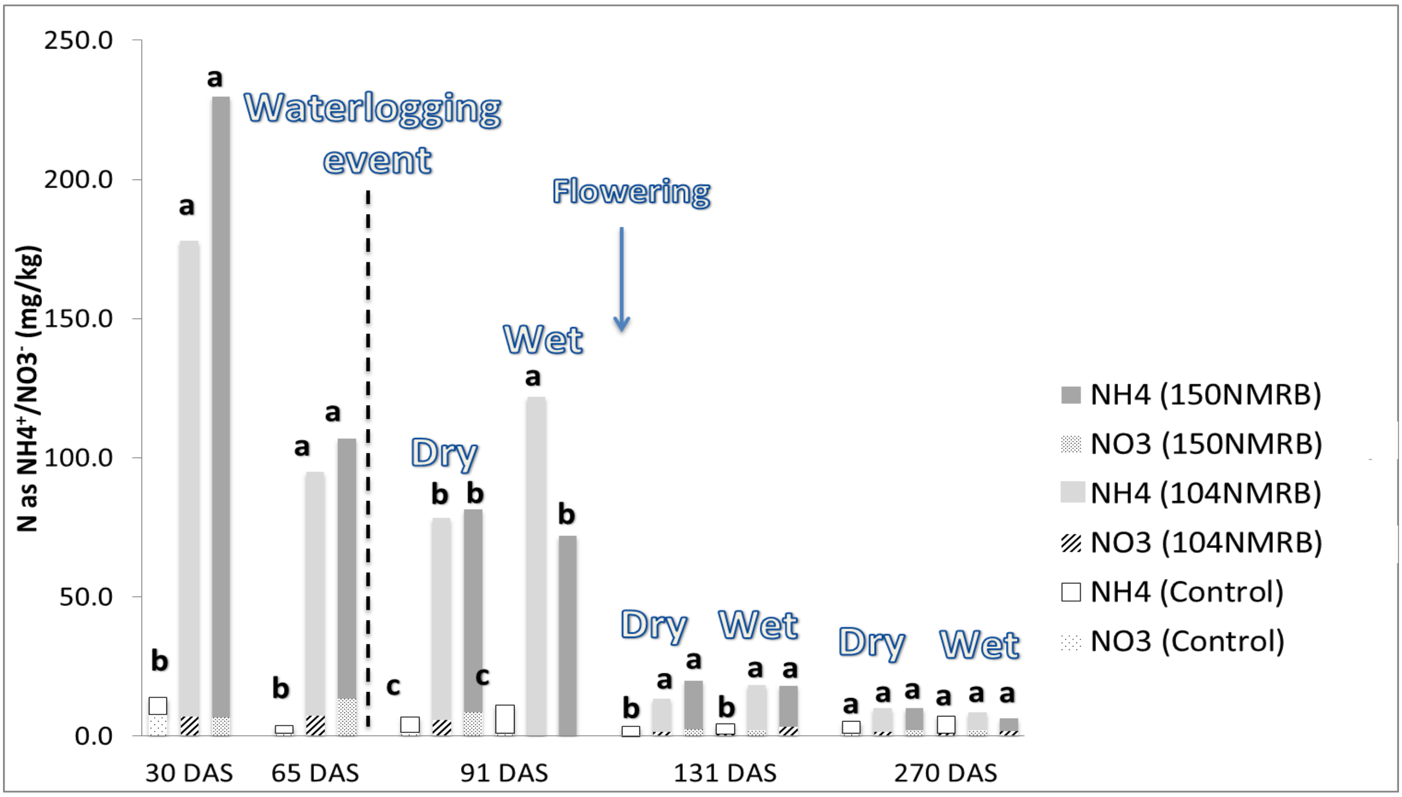

Figure 1: The concentration of N in the sampled mid-row band, present as either $NH4^{+}$ or $NO3^{-}$ (mg/kg) at four different times of sampling, for two mid-row banded N treatments (104NMRB and 150NMRB), for two waterlogging treatments after the imposition of the water-logging event, Moulamein 2017. Columns with the same letter within each time of measurement were not significantly different (P<0.05).

Both mid-row banded treatments gave more heads/m^2 than 15N, similar to 150 NTL, but less than 150 NTE (Table 1). Both mid-row banded treatments gave more grains per head than 15N, but less than either of the top-dressed treatments. All treatments had less grains per head than the accepted size of 30-40 grains for a high-yielding irrigated wheat crop. Grain weight was similar for all treatments. Consequently, both mid-row banded N treatments had more grain yield than 15N, similar to 150NTL but less grain yield than 150NTE.

Both mid-row banded treatments had similar apparent nitrogen recovery efficiency (ANRE) to 150NTL of 18-21%, but less than 150NTE, when waterlogged. 150NTE in particular had a high ANRE when both waterlogged and not waterlogged. When not waterlogged, 104NMRB had similar ANRE to 150NTL, but less than 150NTE, and 150NMRB had the lowest ANRE. In a non-waterlogged environment MRB treatments had an ANRE of 19-31% which reflects previously reported efficiencies of 21-28% in an Australian high rainfall environment (Angus et al.,2014) and 24-31% in south-east China (Chen, 2016). The topdressed treatments had an ANRE of 30-41% which is above the reported rates of 20% in Australia and 27-30% in China.Our topdressing figures are more similar to the global estimate of 33-34% provided by Ladha et al. (2005) and Raun & Johnson (1999). Waterlogging significantly reduced our treatment efficiencies, resulting in an ANRE of 18-22% for MRB treatments and 21-36% for topdressed treatments.

The waterlogging event both reduced CCCI (chlorophyll content of plants) and NDRE (a normalized measure of the canopy chlorophyll and biomass) and also eliminated all N treatment effects (comparing CCCI 2 wet with dry and NDRE 2 wet with dry, immediately after the waterlogging event). They were all the same immediately after the waterlogging event (CCCI 2 and NDRE 2). The topdressed N treatments recovered better after the waterlogging event than the mid-row banded N treatments (comparing ΔCCCI and ΔNDRE, which is the change from measurement 2 to measurement 3). This concurs with the greater grains per head for the topdressed treatments, as the number of grains per head would have been determined in the 2-3 weeks before flowering (or between booting and grain set), which would have started not long after the waterlogging event.

It appears that both topdressed treatments were particularly efficient, as ANRE was relatively high. With reference to the high ANRE of the NTE treatment, we suspect that topdressed N was preserved as ammonium during the subsequent waterlogging and hence was not lost via denitrification.

Table 1: The grain yield (mt.ha^{-1}), grain N (kg.ha^{-1}) and apparent nitrogen recovery efficiency (ANRE, %), yield components, CCCI and NDRE and change in CCCI and NDRE (ΔCCCI and ΔNDRE) after the waterlogging event, for five different N treatments (15N, 150NTE, 150 NTL, 104 NMRB and 150 NMRB) and two irrigation treatments (dry and wet), Moulamein 2017.

		15N	150NTE	150NTL	104NMRB	150NMRB	Dry	Wet
GY		1.66c	3.91a	3.35ab	2.89b	3.068b	2.86A	3.10A
Grain N		25.98c	78.28a	62.02b	49.39b	50.93b	54.41	52.23
ANRE (%)	Dry		41.3a	30.3b	31.1b	19.0c	30.4A	
	Wet		36.1a	20.7b	21.5b	18.1b		24.1B
Heads/m2		407.5c	619.8a	537.6b	592.4ab	530.8b	556.2a	522.4b
Grains/hd		10.03b	17.58a	17.00a	12.70b	14.49ab	12.28b	16.37a
1000 GW		43.40a	39.41c	40.40bc	42.62ab	42.78a	43.26a	39.65b
CCCI 2 (dry)		0.559a	0.596a	0.566a	0.590a	0.598a		
CCCI 2 (wet)		0.513a	0.519a	0.519a	0.526a	0.520a		
CCCI 3 (wet)		0.546c	0.641a	0.606b	0.595b	0.580b		
ΔCCCI (wet)		0.033d	0.122a	0.085b	0.069c	0.060c		
NDRE 2 (dry)		0.266c	0.323a	0.275b	0.334a	0.309a		
NDRE 2 (wet)		0.254a	0.285a	0.265a	0.293a	0.275a		
NDRE 3 (wet)		0.363c	0.510a	0.464b	0.448b	0.429b		
ΔNDRE (wet)		0.109c	0.225a	0.199a	0.155b	0.154b		

6. Conclusion:

Midrow banding preserved much of the N as ammonium until 91 DAS, successfully preserving the N from a waterlogging event. Only 5-8% of the mid-row N was in the mid-row by 131 DAS, just after flowering. When waterlogged, mid-row banded N achieved similar grain yield, grain N and ANRE as topdressing after the waterlogging event, but less than a particularly efficient topdressing before the water-logging event. When dry, the treatment effect was the same. Both topdressed treatments had similar or better ANRE than MRB, the early topdressing probably due to the topdressed N remaining in the ammonium form and surviving the waterlogging event. Wheat with mid-row banded N showed less recovery after the water-logging event, and had fewer grains per head, than either of the topdressed treatments. Hence, the N supply from MRB N to flowering and beyond appeared less than that of topdressed N.

Mid-row banding of N showed an acceptable response in both waterlogged and non-waterlogged conditions, but similar or less than highly effective N topdressing treatments.

7. Recommendations and implications

Mid-row banding appears to be a viable method of reliably supplying high rates of nitrogen in dry or wet years. It should be applicable to most irrigated cropping contexts in the Riverina and beyond, where there are risks of excessively dry or wet conditions. It supplied N to the wheat crop from about 10 weeks after sowing, and preserved the bulk of the MRB N as ammonium. This ensured that little MRB N was lost from the waterlogging event.

MRB had acceptable grain yield and ANRE, but it does not appear to have superior grain yield or ANRE to highly-effective topdressing N applications. More than 90% of the MRB N was gone from the mid-row just after flowering, so post-flowering N nutrition may have been inferior to the topdressed N treatments, which could have explained the observed grain yield and ANRE effects.

Further research on nitrogen recovery of mid-row banding is needed across different irrigation and cropping scenarios to properly quantify if MRB has a similar NUE to topdressing. The data presented in this paper only represents a single year of work, in a low-yielding context, with direct comparisons to topdressing and as such, needs further data to back up results.

8. References

Angus, JF, Gupta, VVSR, Pitson, GD, and Good, AJ (2014) Effects of banded ammonia and urea fertiliser on soil properties and the growth and yield of wheat, *Crop and Pasture Science*, **65**, 337-352

Armstrong, R. (2016, September 16). *The good, the bad and the ugly of topdressing opportunities*. Retrieved 04 06, 2018, from Grains Research and Development Corporation: https://extensionaus.com.au/crop-nutrition/the-good-the-bad-and-the-ugly-of-topdressing-opportunities/

Brar, N. K. (2013). *Nitrogen management in wheat sown into rice crop residues.* Wagga Wagga: Charles Sturt University.

Chen, Z., Wang, H., Liu, X., Liu, Y., Gao, S., & Zhou, J. (2016). The effect of N fertilizer placement on the fate of urea-15N and yield of winter wheat in southeast China . *PLoS ONE*, 11(4): e0153701.

Irvine, R. B., Lafond, G. P., May, W. E., Kutcher, H. R., & Holzapfel, C. B. (2010). Alternative nitrogen management options for winter wheat on the eastern praries of western Canada. *Canadian Journal of Plant Science* , 471-478.

Jones, C. A., Koenig, R. T., Ellsworth, J. W., Brown, B. D., & Jackson, G. D. (2007). *Management of urea fertiliser to minimize volatilization.* Bozeman: Montana State University.

Ladha, J. K., Pathak, H., Krupnik, T. J., Six, J., & van Kessel, C. (2005). Efficiency of fertilizer nitrogen. *Advances in Agronomy*, 87:86-156.

Passioura, JB and Wetselaar, R (1972) Consequences of banding nitrogen fertilizers in the soil. II Effects on the growth of wheat roots. *Plant and Soil* **36:** 461-473

Raun, W. R., & Johnson, G. V. (1999). Improving nitrogen use efficiency for cereal production. *Agronomy Journal*, 91:357-363.

Sandral, G. A., Tavakkoli, E., Harris, F., Koetz, E., & Angus, J. (2017). *Improving nitrogen fertiliser use efficiency in wheat using mid-row banding.* Ballarat: Agronomy Australia Conference.

Tsai, C. Y., Dweikat, I., Huber, D.M., & Warren, H.L. (1992). Interrelationship of nitrogen nutrition with maize (Zea mays) grain yield, nitrogen use efficiency and grain quality. *Journal of the Science of Food and Agriculture,* 58:1-8.

Wetselaar R, Passioura JB, Rose DA, Jakobsen P (1973) Banding nitrogen fertilizers in soil: principles and practice. *Chimie & Industrie – Genie Chimeque* **106:** 567–572.

Zerulla W, Barth T, Dressel J, Erhardt K, Horchler von Locquenghien K, Pasda G, Rädle M, Wissemeier AH (2001) 3,4-Dimethylpyrazolphosphat (DMPP)—a new nitrification inhibitor for agriculture and horticulture *Biol. Fertil. Soils*, **34:** 79–84