Efficient use of N fertilizer in Riverina irrigated cropping – could mid-row banding help?

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Keywords

- Nitrogen fertilizer, banding, irrigation, cropping, Riverina.

Take home messages

- Seasonal conditions can cause poor nitrogen fertilizer uptake in Riverina irrigated crops. Dry winters make it difficult for top-dressed N to reach the root zone. However, placing all N upfront can be problematic due to excessive early plant growth and high nitrogen losses in a wet winter.
- Mid-row banding high rates of N every second row maintains a concentrated zone of ammonium N a distance from the plant row. This reliably becomes available to the plant during the season even in a dry winter, and limits denitrification in a wet winter.
- Mid-row banding trials in rice stubble in 2015 and 2016 showed:
  - The wheat plants accessed the mid-row N about 10 weeks after sowing
  - Apparent fertiliser recovery efficiency was similar to that expected from topdressing in good conditions, despite periods of water-logging during the season

1. Background

Irrigated winter crops in the Riverina need substantial N supply for high, water-productive yields. A 6 $t.ha^{-1}$ wheat crop, for example, needs a supply of about 240 $kgN.ha^{-1}$. For continuous cropping systems in the Riverina, often more than 150 $kgN.ha^{-1}$ of that must come from fertilizer N. How do we get high rates of N to the crop at the appropriate time, with our variable climate? Even with double-shooting systems, generally not all N can be supplied up-front as it causes excessive growth and lodging problems. Most growers top-dress high rates of N in late winter to supply N at an appropriate time.

With an increasing incidence of dry winters in the Riverina, top-dressed N can be lost from volatilization, or sometimes may not be washed into the soil far enough for reliable root access; more than 10 mm of rainfall is required within a few days after a topdressing event for the N to be properly accessible to crop roots, especially on a clay soil with large amounts of decomposing OM immobilising applied N (Angus et al., 2014) before it reaches the soil. Nitrogen losses in this situation can reach 40% (Fowler & Bryndon, 1989). Hence, response to top-dressed N can vary greatly with rainfall (Angus et al., 2014).

In wet winters, the saturated soil profile of a pre-watered crop increases the risk of prolonged periods of water-logging in winter from relatively modest rainfall events. When N is in the nitrate form in a water-logged soil it can quickly be leached below the root zone, or converted to nitrogen gas and a large proportion of it quickly lost to the crop (Zerulla et al., 2001). This is particularly a risk on clay soils in the Riverina, where soil internal drainage rates are low.

Mid-row banding places high rates of N between plant rows allowing more separation between N and the seed. The increased distance delays access to the applied N, as it takes time for crop roots to reach the band (Passioura & Wetselaar, 1972). The authors' on-farm experience with mid-row banding in rice stubble suggests that the crop is capable of accessing applied N about 6-8 weeks after seeding. Mid-row banding urea or ammonia provides a high concentration of ammonium, which can reduce nitrification rates (conversion to nitrate) by inhibiting microbial activity within the vicinity of the banded N (Wetselaar et al., 1973). Wetselaar et al. (1973) found that an ammonium concentration of 2000 ppm 4 weeks after application – which is achieved by applying 120 kgN.ha^{-1} at a 51 cm spacing – reduced nitrification rates by 95%. Ammonium N does not leach or denitrify, so mid-row banding can reduce the risk of N loss if the soil becomes waterlogged, as only limited amounts of nitrate are present at any point in time (Zerulla, 2001). 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.

Our experiments aimed to measure the response of wheat after rice to N applied entirely at seeding by mid-row banding.

2. Method

The experiments were conducted in a burnt rice stubble at Moulamein, NSW. No spring irrigation was applied. Modern dryland wheat varieties were used, as they have a yield potential of 6 t.ha^{-1} and a short growing season reducing the need for irrigation. Table 1 shows details of the experiments. During sowing seed was blocked in every third row and urea (46%) was banded as mid-row fertiliser.

The experiments were a randomized complete-block design, with 4 replicates. Each plot was 19 m wide, 60 m long in 2015 and 150 m long in 2016. A variable rate seeder was used, so that mid-row fertilizer rate could be changed during the seeding process without stopping the machine. Each plot had 10 m border zones at each end, to allow for the seeder rate to equilibrate after changing the rate between plots. The harvest width was 12.0 m.

Table 1: The experiment details from 2015 and 2016.

Year	2015	2016
Wheat variety	Yitpi	Mace

Sowing date	May 23rd	May 22nd
Sowing rate (kg.ha^{-1})	100	100
Seeder row spacing (cm)	26	18
Mid-row band spacing* (cm)	78	54
Fertilizer with seed	160 kg.ha^{-1} Granulock 10Z**	100 kg.ha^{-1} Granulock 10Z** + 50 kg.ha^{-1} urea
Fertilizer in mid-row	0, 125, 250 and 375	0, 125 and 250
(kg.ha^{-1} urea)	(0, 60, 120 and 180 kgN)	(0, 60 and 120 kgN)
Total N rates (kgN.ha^{-1})	16, 76, 136 and 196	30, 90 and 150

* Every third row of the seeder was blocked to seed, and only urea applied in that row.

**Granulock 10Z contains 11%N, 21.8%P, 4%S and 1% Zn

From 40 days after seeding (DAS), until after flowering, the chlorophyll content of the youngest fully-expanded leaf was measured with a SPAD (N Tester©) meter twice a week in 2015, and once a week in 2016. 30 plants were measured in each plot. Plant number, tiller number and head number were measured. At harvest total grain weight, moisture, protein and 1000-grain weight were measured. Both years soil nitrogen was measured as ammonium and nitrate at seeding, and in 2016 the mid-row was measured at harvest.

All statistics were analyzed using the Statistix software package.

3. Results

Water-logging (as indicated by surface water) occurred for approximately four weeks in each season; one event in 2015 and three separate events in 2016 (Figure 1). Significant crop damage and some plant death occurred in 2016, from the combination of selective herbicide (Tralkoxydim) and water-logging. The wheat accessed the mid-row N 84 DAS in 2015 and 86 DAS in 2016 (Figure 1).

The 60N treatment in the mid-row maintained a chlorophyll content equivalent to the highest N rate until 98 DAS in 2015 and 111 DAS in 2016. The 120N treatment, maintained a chlorophyll content equivalent to the highest N rate until 142 DAS in 2015.

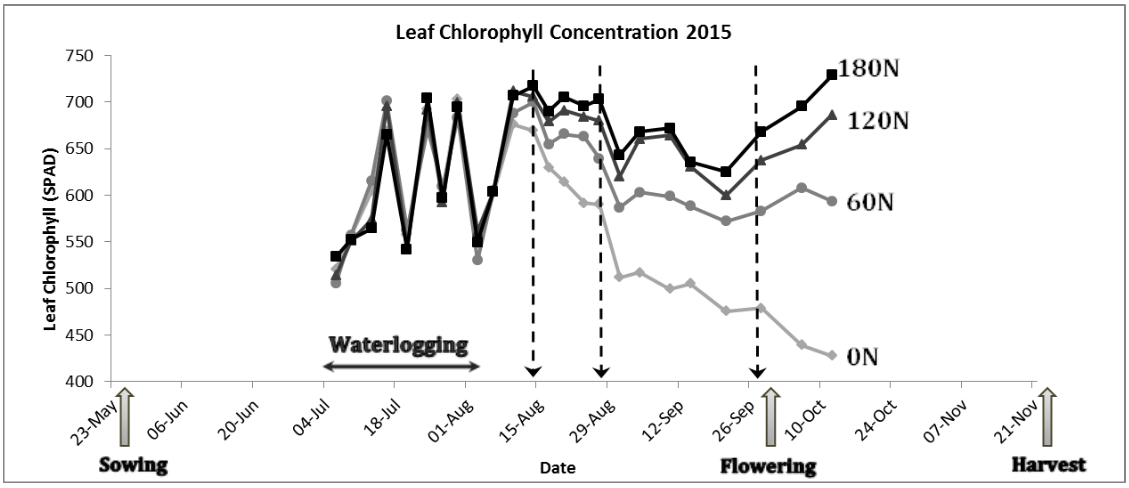

Figure 1a: N Tester© (SPAD) measurements leaf chlorophyll concentration for four mid-row nitrogen treatments (0N, 60N, 120N & 180N) during the 2015 growing season for wheat. Arrows with dotted lines indicate the time when chlorophyll concentration became significantly less than the higher N rates for 0N, 60N and 120N respectively.

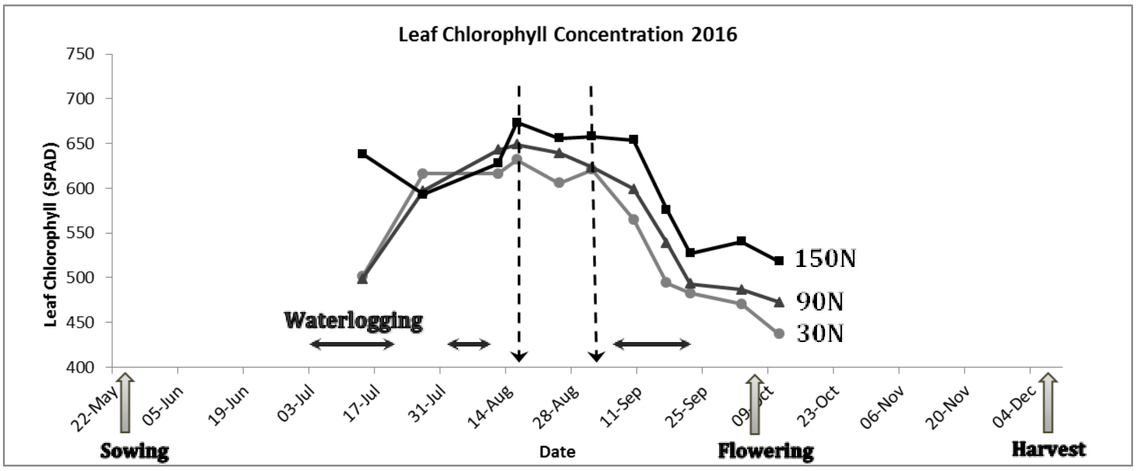

Figure 1b: N Tester© (SPAD) measurements leaf chlorophyll concentration for four mid-row nitrogen treatments (0N, 60N, 120N & 180N) during the 2016 growing season for wheat. Arrows with dotted lines indicate the time when chlorophyll concentration became significantly less than the higher N rates for 0N and 60N respectively.

Mid-row N increased grain yield a similar amount in both seasons; 120 $kgN.ha^{-1}$ increased yield by 1.2-1.3 $t.ha^{-1}$ compared with 0N (Table 2). Mid-row N only increased grain protein in 2015. Consequently, grain N responded more to mid-row N in 2015 than in 2016. The apparent nitrogen recovery efficiency (ANRE) in the grain was greater in 2015 (maximum of 28-30%) than in 2016 (maximum of 17%).

Table 2: The mid-row N rate (kgN.ha^{-1}), total fertilizer N rate (kgN.ha^{-1}), grain yield (mt.ha^{-1}) and grain protein content (%), grain N (kgN.ha^{-1}) and ANRE (%), for four mid-row N treatments in 2015 (0, 60, 120 and 180 kgN.ha^{-1}) and three mid-row N treatments in 2016 (0, 60 and 120 kgN.ha^{-1}), North Dale, Moulamein.

Year	Mid-row N (kg.ha^{-1})	Total N (kg.ha^{-1})	Grain yield (mt.ha^{-1})	Grain protein (%)	Grain number (grains.m^{-2})	1000 grain wt (g)	Grain N (kg.ha^{-1})	ANRE (%)
2015	0	16	1.85c	8.5d	4,410c	43a	28c	-
	60	76	2.73b	9.6c	7,170b	40a	46b	30
	120	136	3.14a	11.3b	9,000a	36b	62a	28
	180	196	2.95ab	12.2a	9,310a	33b	63a	19
2016	0	30	2.95c	8.2a	7,190c	41a	42b	-
	60	90	3.55b	7.8a	8,880b	40a	48b	10
	120	150	4.12a	8.4a	10,300a	40a	62a	17

Column entries followed by different letters are significantly different ($P<0.05$).

4. Discussion

Mid-row N was accessed by the wheat crop from 84-86 DAS, with the 120-180kgN.ha¯1 treatments delivering N until after flowering. At that point the SPAD meter was no longer capable of measuring leaf chlorophyll content, due to a lack of actively growing leaf tissue to sample. When the wheat first accessed the mid-row N, it was at the mid-tillering stage. This is compatible with achieving high yields in the Riverina, because limited early N access moderated early vegetative growth.

The grain yield response to mid-row N was similar in both years; 0.6-0.9 t.ha^{-1} for 60 kgN.ha^{-1} in the mid-row and 1.2-1.3 t.ha^{-1} for 120 kgN.ha^{-1}. Grain protein only responded to mid-row N in 2015. Consequently the response of grain N and thus ANRE, was greater in 2015. The protein response can be attributed to a much drier spring in 2015 spring than 2016, only receiving 20 mm of rainfall in September and October compared to 119 mm in 2016. There was also a week of unseasonably hot weather just after flowering, with maximum temperature ranging from 31-40°C. Gibson & Paulson (1999) reported a 3-5% reduction in yield for every one degree increase in average daily temperature above 15°C. 1000-grain weight did not decline with increased mid-row N in 2016 as it did in 2015, but the yield response was similar to 2015. If yield components in 2016 had reflected the 2015 season, then yield should have been greater in the second year due to a more favourable season. However, grain number (the product of head number and grains per head) did not respond as much to mid-row N in 2016. This may have been due to the crop damage from combined herbicide and water-logging that occurred in 2016.

The measured ANRE of 17-30% was similar to that for mid-row N of 21-28% in an Australian high rainfall environment (Angus et al., 2014) and 24-31% in south-east China (Chen, 2016), although it was much lower than the 40-100% found by Hartmann et al. (2015) in a maize-wheat system in northern China. It was also similar to ANRE of top-dressed N in the above experiments of 20% in Australia and 27-30% in south-east China. It is lower than the global estimate of 34% by Ladha et al. (2005).

Although detailed soil N measurements were not taken, the ANRE estimates suggest a substantial proportion of the mid-row N survived the water-logging events. This may have been due to the high concentration of N in the mid-row band inhibiting nitrification of ammonium to nitrate (which is then vulnerable to denitrification in a water-logged soil), such as described by Wetselaar et al. (1973) and Zerulla et al. (2001).

Our GRDC-funded experiment in 2017 follows a similar method, but includes a winter water-logging treatment. We have replicated soil matric potential and redox measurement, both to ensure the water-logging event is thorough and to accurately characterize soil condition during and after the event. We have also included two top-dressed N treatments; topdressing 250 $kg.ha^{-1}$ of urea either before or after the water-logging event. In addition, we are sampling N concentration in the mid-row 4 times during the season and comparing the concentration of nitrate to ammonium to follow the fate of the mid-row N as the season progresses.

5. Conclusions

Mid-row banded N increased yield in wheat after rice, despite significant water-logging in both seasons. The response of grain protein, grain N, and consequent ANRE, was greater in 2015 than in 2016; potentially due to waterlogging and crop damage limiting grain yield response in 2016. ANRE to mid-row banded N was similar to that found in other studies and similar to results for top-dressed urea in a similar environment.

SPAD measurements indicated that most mid-row banded N survived the substantial water-logging events in both seasons, with wheat still accessing N after flowering. This may make it a helpful technique for situations with an elevated water-logging risk, such as pre-watered irrigated crops or crops after rice.

6. References

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