Reliable one-pass nutrition: mid-row banding high nitrogen rates in irrigated wheat

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Abstract
Irrigated winter cropping requires high nitrogen fertiliser rates for high yields, usually applied in multiple topdressing operations. Mid-row banding (MRB) of nitrogen fertiliser enables the entire requirement to be applied at seeding. Physical separation delays plant access, whilst high ammonium concentration inhibits nitrification to nitrate, further delaying plant access and reducing potential leaching and denitrification, to deliver a steady supply of nitrate to the growing crop. Five experiments between 2015 and 2020 assessed the timing of crop access to mid-row banded nitrogen, and its effect on wheat yield and protein.

The wheat crop accessed the mid-row band 54-84 days after seeding; less time with a narrower inter-row, equating to 1.0 days per centimetre of inter-row. In 2017 in a rice system, the Apparent Nitrogen Recovery Efficiency (ANRE) of wheat to 135 kg/ha of MRB nitrogen was 19%, less than that of topdressing. In 2018 in a border-check irrigated winter crop system, the ANRE to 135 kg/ha of MRB nitrogen was 30%, the same as for topdressing. In 2020 in a pivot-irrigated winter crop system, the ANRE of wheat to 135 kg/ha of MRB nitrogen was 60%, and to 240 kg/ha MRB nitrogen was 50%, similar to that of top-dressed nitrogen. 240 kgN/ha mid-row banded at seeding increased grain yield by 4.27 t/ha to 9.19 t/ha and increased grain N by 120 kg/ha, without any crop lodging.

Mid-row banding at seeding appears to be a reliable and efficient method of applying high nitrogen rates to wheat, in both a rice system and irrigated winter cropping system.

Keywords
Mid-row banding, nitrogen, irrigation, ANRE

Introduction
Irrigated cropping systems in south-east Australia usually require high rates of fertilizer nitrogen for high yields and water productivity. Currently, growers are limited to using in-season top-dressing to supply high nitrogen rates to avoid damage to germinating seed, excessive early growth and crop lodging. Top-dressed nitrogen requires extra operations, and is vulnerable to denitrification in very wet seasons and lack of timely rain to wash it into the root zone in dry seasons which can lead to volatilisation, especially with declining winter rainfall (Hochman et al., 2017).

Mid-row banding (MRB) can place high rates of nitrogen in the crop inter-row, providing the entire nitrogen fertiliser requirement whilst avoiding crop access to the nitrogen early in the season and damage to the germinating seed. Mid-row banded nitrogen is preserved in the ammonium form for longer as nitrification is limited (Wetselaar et al., 1972 and Wetselaar et al., 1973), which limits denitrification in water-logged conditions and provide a prolonged flux of nitrate nitrogen to the crop.

These experiments aimed to gauge the response of wheat to high rates of mid-row banded nitrogen, in an irrigated rice system and an irrigated winter cropping system in south-east Australia.

Methods
Treatments and design
The experiments were conducted during five seasons between 2015 and 2020 inclusive. The experiments in 2015, 2016 and 2017 were conducted in within a rice-wheat system; wheat is seeded shortly after rice harvest, and other winter crops or pastures are grown in subsequent seasons before rice. The experiments in 2018 and 2020 were border-check irrigated and centre-pivot irrigated winter

cropping systems respectively. Centre-pivot irrigation in 2020 was scheduled according to soil moisture tension; the other experiments were not.

All experiments were a randomised complete block design, with four replicates. Plants/m^2, heads/m^2, 1000 grain weight, grain yield, grain moisture content and grain protein were measured in every experiment. In 2015, 2017 and 2020, apparent leaf chlorophyll content of the youngest emerged leaf in all MRB plots and the control plots, with 30 repetitions per plot. Measurements were taken twice-weekly from 40 days post-sowing until the apparent leaf chlorophyll content of the MRB plots had diverged from that of the control plots, then weekly after that. The data was analysed using one or two way ANOVA using the Statistix software package (Tallahassee, FL, USA).

Table 1. The soil type, soil N at seeding (kgN/ha) and mid-row banded (MRB) and topdressed (TD) nitrogen treatments applied in the experiments, 2015-2020.

Season	*Soil type*	*Soil N (kgN/ha)*	*Nitrogen treatments*
2015	Grey sodic clay	50	0, 60, 120, 180 kgN/ha in MRB
2016	Grey self-mulching clay	67	0, 60 and 120 kgN/ha in MRB
2017	Grey self-mulching clay	55	0 and 135 kgN/ha in MRB 135 kgN/ha TD at GS31 135 kgN/ha TD at GS33
2018	Grey self-mulching clay	72	0 and 135 kgN/ha in MRB 135 kgN/ha TD at GS31
2020	Calcareous sandy loam	76	0, 135 and 240 kgN/ha in MRB 135 kgN/ha TD at GS24, 31 240 kgN/ha TD at GS24, 31, 59

Table 2. A summary of crop management for the experiments, 2015-2020. The year and GSR for that year (April to October rainfall inclusive), prior history, sowing date, variety and seed rate, seed row and mid-row band inter-row spacing, starter fertiliser, topdressing date and harvest date.

Year & GSR	*History*	*Sow date*	*Variety, rate (kg/ha)*	*Seed row, MRB inter-row spacing (cm)*	*Starter fertiliser (in seed row)*	*Topdress date*	*Harvest date*
2015 190mm	Post-rice	23/5	Yitpi, 90	27, 54	160 kg/ha Granulock*	-	2/12
2016 330mm	Post-rice	22/5	Mace, 100	18, 36	100 kg/ha Granulock* + 50 kg/ha urea	-	5/12
2017 202mm	Post-barley (rice layout) (1 SI)	17/5	Mace, 85	18, 36	150 kg/ha MAP + 1% Zn	28/7 14/8	30/11
2018 84 mm	Post-canola (Br.check) (1 PSI, 2 SI)	15/5	Mace, 80	26, 26	100 kg/ha DAP + 1% Zn	18/8	9/12
2020 239mm	Post-canola (pivot irrig.)	23/5	Rockstar 100	26, 26	100 kg/ha MAP + 1%Zn	16/7 25/8 17/9	12/12

MAP = monoammonium phosphate (10% N, 20% P), DAP = diammonium phosphate (20% N, 20% P), PSI = pre-sowing irrigation, SI = spring irrigation. * Granulock: 11% N, 21.8% P, 4% S, 1.0% Zn.

Results and discussion

Timing of mid-row nitrogen availability

In 2015, with 54 cm between MRB nitrogen bands, the apparent leaf chlorophyll content of mid-row banded treatments diverged from that of the 0 kgN/ha control at 84 days (data not shown). Hence, it is assumed that the mid-row banded nitrogen was accessed at 84 days. In 2017, with a 36 cm MRB inter-row, the MRB nitrogen was accessed at 72 days after seeding. In 2020, with a 26 cm MRB inter-row, the MRB nitrogen was accessed 54-57 days after seeding. These results suggest with a smaller MRB inter-row the wheat roots require less time to reach the mid-row band: 1.0 days per centimetre of inter-row. Passiora and Wetselaar (1972) showed crop roots grew across to the mid-row band and surrounded it. The timing of access to MRB nitrogen with a 26 cm MRB inter-row coincides with early-to-mid tillering, ideal for high-yielding irrigated wheat. Conversely, the timing of access with a 54 cm inter-row of 84 days coincides with late tillering; probably a bit late to achieve high yields, particularly if soil nitrogen is low.

Wheat grain yield and nitrogen response

In a rice-wheat system, the yields were not as high as would be expected in a fully-irrigated wheat crop (Table 3). They are still relevant to higher-yielding irrigated cropping on heavy clay soils in particular, as they also encounter less favourable conditions sometimes, particularly water-logging. The experiment in 2015 incurred water-logging during the season and drought stress later in the season, in 2016 a combination of water-logging and herbicide damage, and in 2017 had no irrigation until spring. In 2015, MRB nitrogen gave an ANRE of 19-30%. In 2017, the response to MRB nitrogen was less than to topdressed nitrogen.

Table 3. Grain yield, grain N and ANRE for control, mid-row banded (MRB) and topdressed (TD) treatments, in a rice system and an irrigated winter cropping system, 2015-2020.

Year	*Treatment*	*MRB/TD N (kg/ha)*	*Grain yield (t/ha)*	*Grain N (kg/ha)*	*ANRE*
Rice-wheat system:					
2015	Control	0	1.85^{c}	28^{c}	-
	60N MRB	60	2.73^{b}	46^{b}	30^{a}
	120N MRB	120	3.14^{a}	62^{a}	28^{a}
	180N MRB	180	2.95^{ab}	63^{a}	19^{b}
2016*	Control	0	2.95^{c}	42^{b}	-
	60N MRB	60	3.55^{b}	48^{b}	10^{b}
	120N MRB	120	4.21^{a}	62^{a}	17^{a}
2017	Control	0	1.66^{c}	23^{d}	-
	135N MRB	135	3.07^{ab}	51^{bc}	19^{c}
	135N TD GS31	135	3.91^{a}	78^{a}	41^{a}
	135N TD GS33	135	3.35^{ab}	62^{b}	30^{b}
Winter crop system:					
2018 (border-check irrigated)	Control	0	3.62^{b}	55^{b}	-
	135N MRB	135	5.08^{a}	95^{a}	30^{a}
	135N TD	135	4.93^{a}	93^{a}	28^{a}
2020 (pivot-irrigated)	Control	0	4.92^{c}	78^{c}	-
	135N MRB	135	7.75^{b}	155^{b}	60^{a}
	240 N MRB	240	9.19^{a}	198^{a}	50^{ab}
	135N TD	135	7.68^{b}	152^{b}	55^{ab}
	240N TD	240	8.42^{ab}	182^{a}	43^{b}

*The 2016 trial was severely affected by a combination of water-logging and herbicide damage.

In an irrigated winter cropping system, the grain yield and grain N were higher than the rice system for all nitrogen treatments (Table 3). On border-check irrigation in 2018, the response to MRB nitrogen was similar to topdressing. In 2020 under centre-pivot irrigation, the nitrogen response was double that of 2018, but the response to MRB nitrogen was again similar to topdressing. There was no crop lodging in the experiment, even at 240 kgN/ha.

MRB nitrogen gave less response to topdressing in wheat in a rice system in 2017, and similar response in border-check irrigated wheat in 2018. The ANRE was comparable to 21-28% in high-rainfall environments (Angus et al., 2014), 24-31% in south-east China (Chen et al., 2016) and an AARFN (including all plant parts) of 36% in dryland Australian wheat in favourable agronomic conditions (Angus and Grace, 2017). In pivot-irrigated wheat in 2020, MRB nitrogen created a much greater yield response and ANRE, similar to that of topdressing. Presumably, it was only with centre-pivot irrigation, with irrigation scheduled according to soil moisture tension, that soil moisture was rarely a limit during the growing season, allowing the nitrogen response to be better observed with the higher yield potential. The similar response to MRB and topdressing disagrees with the findings of Sandral et al. (2017); that study found a greater response to MRB nitrogen than to top-dressed nitrogen.

Conclusion

Mid-row banded nitrogen produced an ANRE of 19% in a rice-wheat system in 2017, less than top-dressed nitrogen. It produced an ANRE of 30% in border-check irrigated wheat in 2018, similar to top-dressed nitrogen. The response of wheat to mid-row banded nitrogen was much greater in 2020 in the centre-pivot irrigated wheat; an ANRE of 50-60%, similar to that of top-dressed nitrogen. 240 kg/ha of mid-row banded nitrogen enabled a wheat yield of 9.19 t/ha, at an ANRE of 50% and no crop lodging.

The timing for irrigated wheat to begin to access MRB nitrogen of 55-84 days appears appropriate, particularly 55 days with the 26 cm inter-row, as it approximately corresponds with early-to-mid tillering. Within the range of 26 cm to 54 cm MRB inter-row tested, the wheat appeared to require 1.0 extra days to access the MRB nitrogen for each extra centimetre of inter-row spacing.

Mid-row banding at seeding appears to be a valid and efficient method of applying high rates of nitrogen in irrigated systems, where yield potential is known with some confidence, fertiliser nitrogen requirements can be high and growers wish to reduce or avoid reliance on topdressing nitrogen.

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