MANAGING N FERTILISER TO PROFITABLY CLOSE YIELD GAPS

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TAKE HOME MESSAGES

- In low rainfall environments with heavy soils, applied N surplus to crop requirements is available for use by subsequent crops.
- Most profitable treatments to-date are Yield Prophet® (75 per cent and 50 per cent probability) and N bank (100 and 125kg/ha N) systems.
- Over application of N has been more profitable than under application.

BACKGROUND

Australian wheat yields are only half what they could be for the rainfall received (Hochman *et al.* 2017). Nitrogen (N) deficiency is the single biggest factor contributing to this yield gap. This is also likely to be true for other non-legume crops (barley, canola and oats) which reduces farm profitability and global food security. Alleviating N deficiency would increase national wheat yields by 40 per cent (Hochman and Horan 2018).

On farms with no legume pastures, most of the crop N supply must come from fertiliser. Grain legumes do not provide enough N to support yield of subsequent crops at the intensity at which they are currently grown. N fertiliser is a costly input and use of it increases cost of production and value-at-risk for growers. Growers fear that over-fertilisation will result in 'haying off', which reduces both yield and quality. There is also concern that overapplied fertiliser not used by crops is lost to the environment by leaching, volatilisation and denitrification. Consequently, efforts are made to match N fertiliser inputs to seasonal yield potential. This is difficult in southern Australia due to the lack of accurate seasonal forecasts for rainfall.

The difficulty in matching N supply to crop demand and a tendency for growers to be conservative in their N inputs is responsible for a large proportion of the yield gap that can be explained by N deficiency. Chronic N deficiency has also caused soil organic matter to decline and driven a rise in the proportion of low protein grain produced in Australia, which has eroded our standing as a producer of quality wheat in export markets.

AIM

To evaluate different nitrogen management systems designed to profitably close the yield gap due to N deficiency.

PADDOCK DETAILS

Location:	Curyo
Crop year rainfall (Nov-Oct):	2018 – 200mm
	2019 – 368mm
GSR (Apr-Oct):	2018 – 138mm
	2019 – 149mm
Soil type:	Sandy loam top-soil with clay content and calcium carbonate increasing with depth
Paddock history:	2017 – Lentil

TRIAL DETAILS

Crop types:	2018 – Scepter wheat
	2019 – Hyola 350 TT canola
Treatments:	Refer to Table 1
Seeding equipment:	Knife points, press wheels, 30cm row spacing
Sowing date:	14 May 2018 29 April 2019
Replicates:	Four
Harvest date:	15 November 2018 15 November 2019

TRIAL INPUTS

Fertiliser:	Refer to Table 2 and Table 3 for nitrogen fertiliser applications in 2018 and 2019
	2018 – Urea @ 35kg/ha at sowing (host farmer management)
	2019 – Granulock® Supreme Z @ 60kg/ha at sowing

Weeds, pests and disease were controlled according to best management practice.

METHOD

A long-term experiment using a complete randomised block design was established in 2018 to evaluate the performance of different N management systems. Two different systems were tested:

1. Matching N fertiliser to seasonal yield potential (Yield Prophet®)
2. Maintaining a base level of fertility using N fertiliser (N banks)

Within each of these systems there were different treatments targeting different yield potentials (Table 1). In the Yield Prophet® treatment, water limited potential yield was determined at different levels of probability and the amount of N required to achieve these yields applied, assuming a requirement of 40kg/ha N per t/ha wheat yield and 80kg/ha N per t/ha canola yield (Figure 1).

For the N bank treatments there were different target levels of N fertility (N banks). N fertiliser rate in these treatments was calculated as the N bank value minus soil mineral N (kg/ha) measured prior to sowing.

Table 1. Nitrogen management systems and treatments used in the experiments.

System	Treatment	Description
Nil	Nil	No nitrogen applied other than in starter fertiliser
Nitrogen banks (kg/ha N)	50	Soil mineral N + fertiliser = 50kg/ha N
	75	Soil mineral N + fertiliser = 75kg/ha N
	100	Soil mineral N + fertiliser = 100kg/ha N
	125	Soil mineral N + fertiliser = 125kg/ha N
	150	Soil mineral N + fertiliser = 150kg/ha N
Yield Prophet® probabilities	100%	Yield with lowest yielding season finish on record
	75%	Yield with lower yielding quartile season finish (decile 2.5)
	50%	Yield with median season finish (decile 5)
	25%	Yield with higher yielding quartile season finish (decile 7.5)

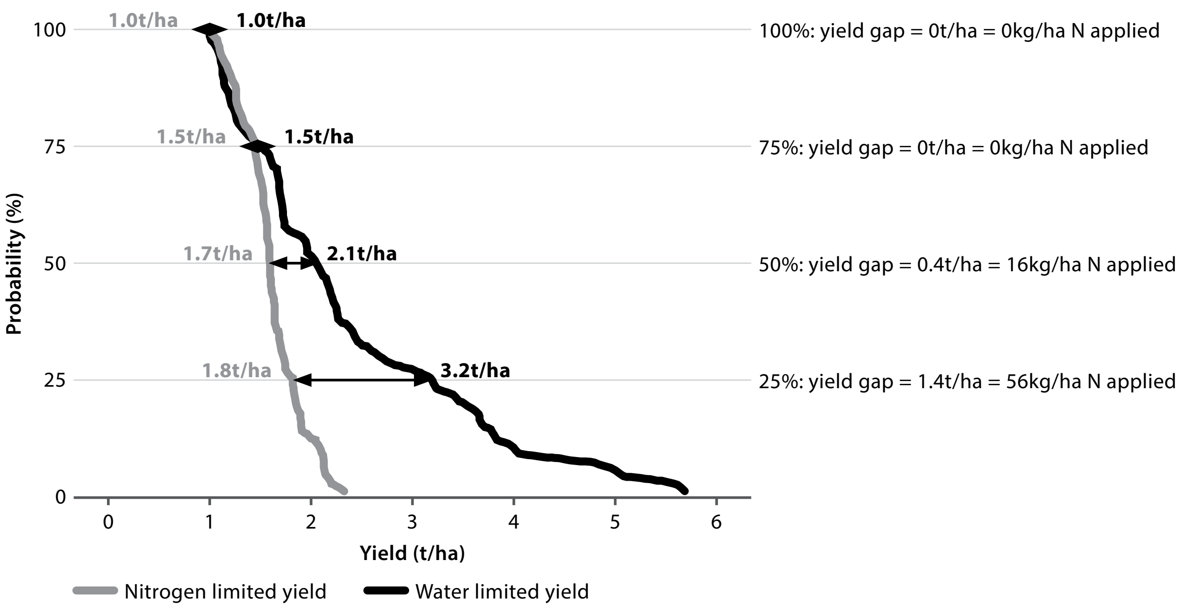

Figure 1. An example from 2018 of how Yield Prophet® is used to determine water limited potential yield given probabilities of different season outcomes, and how this is used to calculate a yield gap and the N fertiliser rate required to close the yield gap.

All gross margins were calculated using values from the 2019 SAGIT Gross Margin Guide (SAGIT 2019).

RESULTS AND INTERPRETATION

2018

In 2018 there was 47kg/ha mineral N (nitrate + ammonium) in the top 1.0m of soil when measured before sowing. The trial was implemented in an area of farmer managed crop which had received 16kg/ha N applied in-furrow as urea at seeding. Scepter was dry sown on 14 May and did not emerge until after enough rain fell to wet the seed bed in the last week of May. Urea was top-dressed on 28 August (crop at GS32) according to the different treatment criteria in Table 1 and only 8mm of rain fell in the 45 days after application.

The dry conditions following application meant there was no crop uptake of top-dressed fertiliser N, with no significant differences observed in crop biomass or N uptake at flowering (data not shown) or grain yield and protein (Table 2). Mean yield was 1.6t/ha and mean grain protein content was 10 per cent indicating that yield was N limited despite the dry seasonal conditions (Holford *et al.* 1992). There were no treatment effects on screenings or test weight, and gross margins for each treatment were calculated assuming 1.6t/ha yield and APW quality. Differences in gross margin are due to different rates of N fertiliser application (Table 2).

Table 2. Amount of N fertiliser top-dressed, wheat grain yield, grain protein and gross margin for all treatments in 2018.

Strategy	Treatment	Top-dressed N (kg/ha)	Grain yield (t/ha)	Grain protein (%)	Gross margin ($/ha)
Nil	Nil	0	1.5	10.0	131
Nitrogen banks (kg/ha N)	50	0	1.6	9.6	131
	75	28	1.7	9.7	98
	100	53	1.8	9.8	69
	125	78	1.5	10.4	40
	150	103	1.5	10.2	10
Yield Prophet® probabilities	100%	0	1.5	9.7	131
	75%	0	1.6	10.4	131
	50%	16	1.5	10.1	112
	25%	56	1.7	10.3	65
	MEAN	**33**	**1.6**	**10.0**	
		Sig. diff. LSD (P=0.05)	**0.694 NS**	**0.310 NS**	

2019

In 2019 there was an additional 0.6kg/ha of mineral N measured prior to sowing for every kg/ha N top-dressed in 2018 (Figure 2 and Table 3). This indicates the majority of applied N not used by the crop in 2018 was carried over for use by 2019 crop in mineral form. Of the remainder of the N applied in 2018 and not measured in soil N, some would have been immobilised into organic form, and some possibly lost due to volatilisation and/or denitrification. Despite 200mm of rain falling in a single event from 11 to 15 December 2018, there appears to have been little leaching, as demonstrated by no significant difference in mineral N at 0.7-1.0m between treatments (Figure 3). Low levels of loss and carryover of unused N in low rainfall environments with heavy soils corroborate recently published studies from southern NSW (Smith *et al.* 2019).

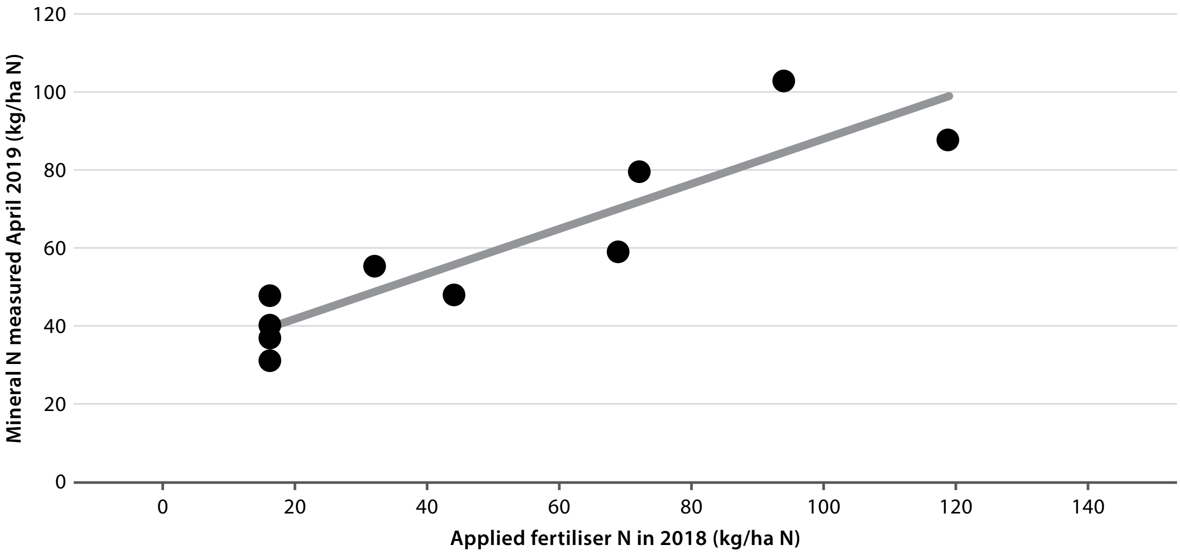

Figure 2. The relationship between fertiliser N applied in 2018 and soil mineral N (nitrate + ammonium) measured prior to sowing in 2019. Linear regression is of the form y=0.6x + 30 (P<0.001, R=0.80) meaning that for every 1kg/ha of N fertiliser applied in 2018, 0.6kg/ha was available as mineral N prior to sowing in 2019.

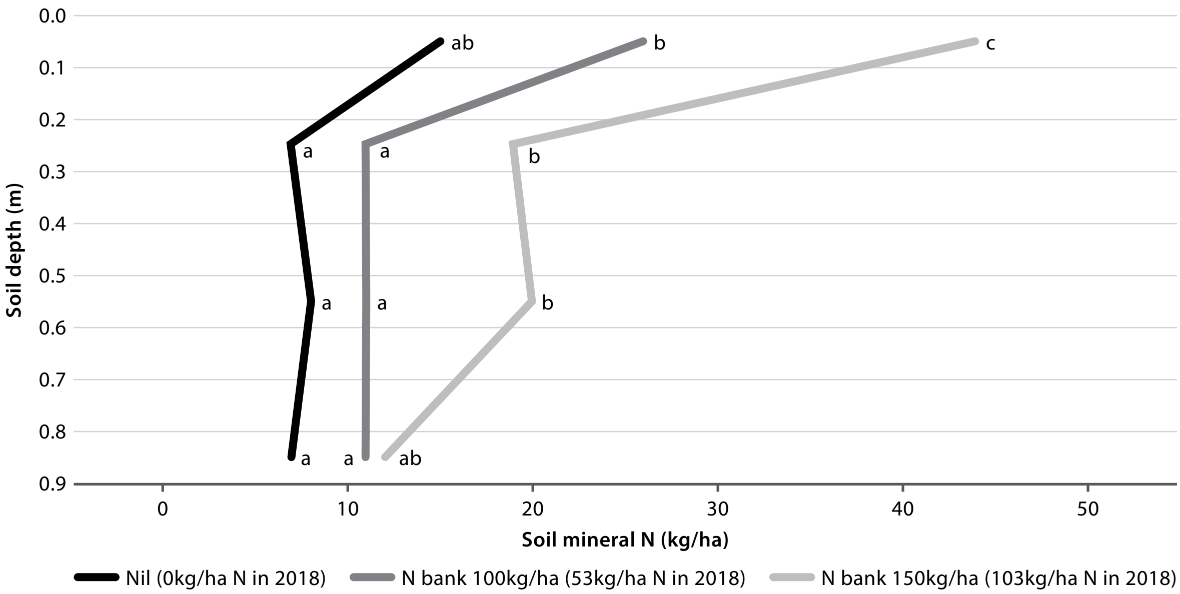

Figure 3. Soil mineral N (nitrate + ammonium) content of the soil profile in three contrasting treatments measured prior to sowing in 2019. Letters indicate significant difference between means (P=0.05).

The canola crop was top-dressed on 28 June (six leaf) at different rates (Table 3) according to the treatment criteria in Table 1. Yield was strongly related to total N supply (soil mineral N + fertiliser N) and maximised at ~100 kg/ha N (Figure 4). Oil concentration was negatively affected by N supply (Table 3). Increase in yield during the linear phase of the response validated current rules of thumb with 83kg/ha N being required per t/ha of canola grain yield up to 90 per cent of water limited potential yield.

Table 3. Soil mineral N, amount of N fertiliser top-dressed, canola grain yield, grain oil and gross margin for all treatments in 2019.

Strategy	Treatment	Soil mineral N (kg/ha)	Top-dressed N (kg/ha)	Grain yield (t/ha)	Grain oil (%)	Gross margin ($/ha)
Nil	Nil	37	0	1.2	43.7	226
Nitrogen banks (kg/ha N)	50	31	20	1.4	44.3	298
	75	48	31	1.8	43.4	488
	100	59	42	2.4	42.3	810
	125	103	25	2.4	41.7	810
	150	88	57	2.2	40.2	618
Yield Prophet® probabilities	100%	40	24	1.4	44.4	300
	75%	48	88	2.4	41.9	734
	50%	55	112	2.5	40.4	730
	25%	80	112	2.4	39.7	655
	Sig. diff.	**<0.001**		**<0.001**	**<0.001**	
	LSD (P=0.05)	**17**		**0.5**	**0.7**	

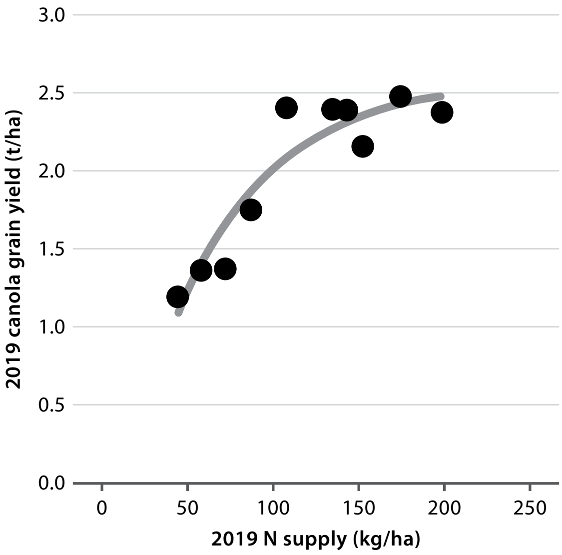

Figure 4. The relationship between N supply (soil mineral N + applied N fertiliser) and canola grain yield in 2019. Fitted exponential function is of the form $y = 2.6 - 3.2(1.0^{x})$ ($P<0.001$, $R=0.85$).

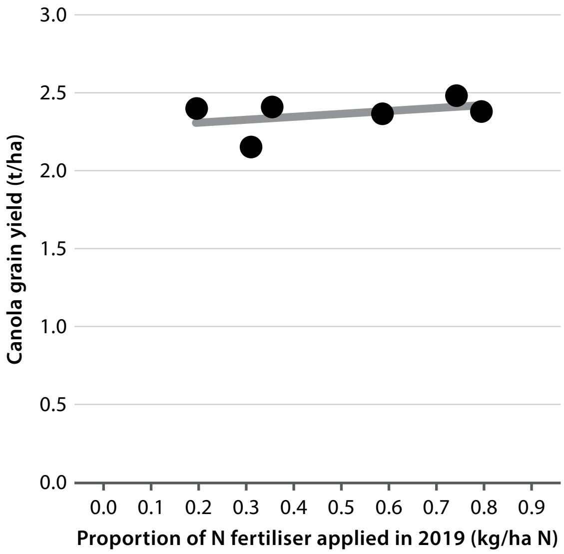

Figure 5. The relationship between the proportion of total fertiliser N applied in 2019 and 2019 canola grain yield. The fitted function is not significant (P=0.395).

Within treatments that were not N limited, there was no relationship between the proportion of total N fertiliser applied in 2019 (Figure 5). This indicates that N fertiliser applied in 2018 and not used in that year was used as efficiently by the 2019 crop as N applied in 2019.

Two-year summary

There was a parabolic relationship between mean application rates for the different treatments and gross margin (Figure 6). The most profitable treatments to date are Yield Prophet® 75 per cent and 50 per cent probability and N bank 100 and 125kg/ha treatments. These treatments averaged 50-70kg/ha N top-dressed per year. Treatments that under applied N are less profitable than treatments that over apply. This is partly due to poor marginal nitrogen use efficiency (NUE, kg/ha grain produced per kg/ha N applied relative to the nil control) of low rates of N application (Figure 7). The reasons for this low NUE are unclear but could be due to microbial immobilisation or low levels of N contributing to vegetative, but not reproductive, growth.

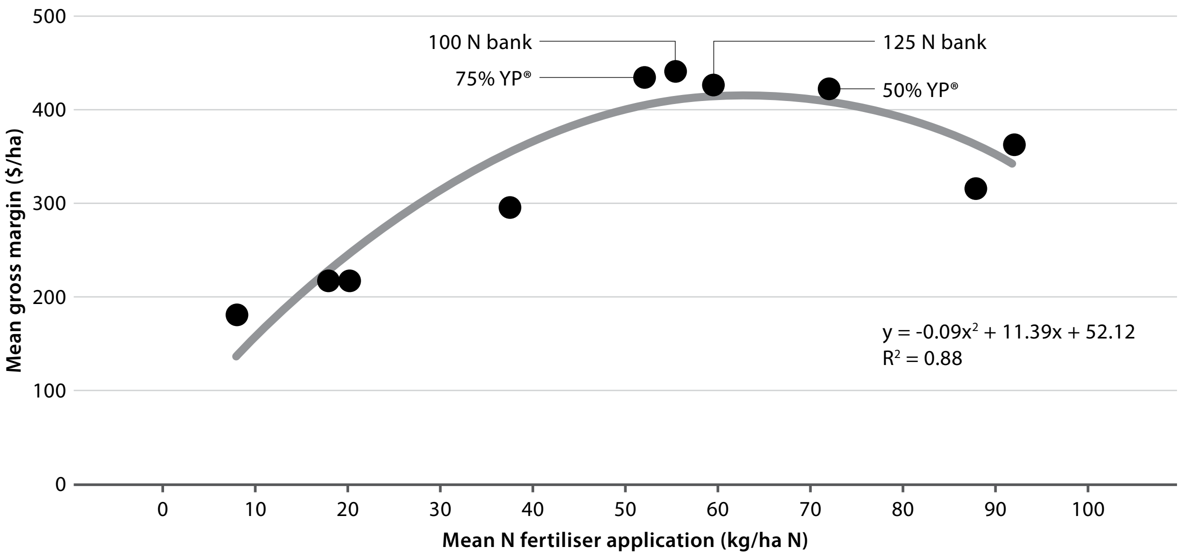

Figure 6. The relationship between two year mean annual fertiliser N application and mean annual gross margin of the different treatments.

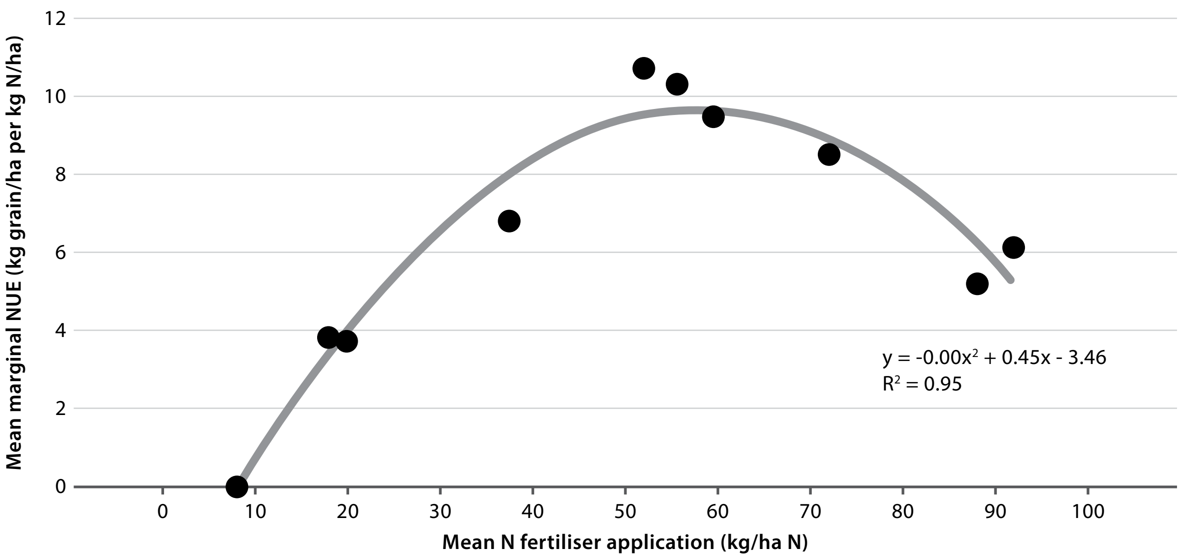

Figure 7. The relationship between mean annual fertiliser N application and marginal nitrogen use efficiency (kg/ha grain per kg/ha N applied relative to the nil control).

COMMERCIAL PRACTICE

Growers should use soil nitrogen tests in combination with Yield Prophet® or an N bank target to ensure they have applied enough N to achieve water limited potential yield and optimise profitability. Long-term profitability is likely to be increased by being less conservative with N fertiliser applications, particularly for growers consistently achieving cereal grain proteins of less than 10.5 per cent (ie. ASW). Growers in low rainfall regions with heavy textured soils can be confident that applied N not used in year of application will remain in the soil for use in subsequent seasons and is not a lost cost.

Further research is required to confirm the robustness of these results over different sites and seasons to ensure there are no negative consequences (eg. haying off or environmental losses) due to maintaining high levels of soil mineral N as per the N bank treatments.

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