MAKING CALCULATED DECISIONS IN HIGH AND LOW STARTING N SCENARIOS

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TAKE HOME MESSAGES

- Depleting soil nitrogen can lead to lower yields and lower protein in wheat and may not be a cost-effective strategy.
- In paddocks with low starting nitrogen and good stored soil moisture, delaying urea applications until GS30/late July may decrease yields and grain protein.
- Soil testing is an important tool to understand the nitrogen status of each paddock to make an informed decision about applying nitrogen.

BACKGROUND

Following the 180mm rainfall event in the Birchip district during December 2018, the 2019 season was set up with a full profile of stored soil moisture where summer weeds were controlled. Knowing that soil moisture should not be a problem early in the season, but with a forecast for a dry spring, farmers faced a conundrum: how much nitrogen (N) should be applied to capitalise on the large yield potential?

If insufficient N was applied, yield potential would be lost, and lower grain protein could result in grain not making the grade at the testing stand – both contributing to a smaller pay cheque for the farmer. But if too much N was applied, especially early, too much biomass might grow, drying out the soil profile and haying off crops. This also would lower yield, increase screenings and put less money in the bank.

So, how much N is the right amount to apply to walk this fine line? What tools can be used to help with this decision? And at what growth stage should N be applied in wheat? This series of trials aimed to answer these questions.

AIM

To investigate which N strategies (timing of application and rates of application) would increase wheat yield and protein in the 2019 season, in paddocks with high or low starting levels of soil N.

PADDOCK DETAILS

Location:	Two paddocks – High N (Karyrie East) and Low N (Karyrie West)
Crop year rainfall (Nov-Oct):	418mm
GSR (Apr-Oct):	197mm (Decile 3)
Soil type:	Clay Loam
Paddock history:	West: 2018 – Barley, 2017 – Lentil East: 2018 – Fallow, 2017 – Lentil

TRIAL DETAILS

Crop type:	Scepter wheat
Treatments:	Refer to Table 1
Target plant density:	130 plants/m^2
Seeding equipment:	Knife points, press wheels, 30cm row spacing
Sowing date:	16 May 2019
Replicates:	Four
Harvest date:	24 November 2019

TRIAL INPUTS

Fertiliser:	Refer to Table 1 and Table 2

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

METHOD

Three complete randomised block trials were sown in two neighbouring paddocks. Two trials, one on the high N site (East, 79kg N/ha (0-100 cm)) and one on the low N site (West, 20kg N/ha (0-100cm)), examined the effect of N application rates on yield and quality, using different decision-making criteria to determine how much N should be applied (Table 1). Rates for the N rate trials were calculated at GS16-19 (July 16) using three decision support tools: Yield Prophet®, French and Schultz (assuming a Decile 5 finish), and Sadras and Angus (also assuming a Decile 5 finish). Nitrogen applications for French and Schultz (Decile 5), and Sadras and Angus (Decile 5) were calculated assuming a crop requirement of 40kg N/ha to produce 1t/ha of grain at 11 per cent protein. All treatments were calculated using available stored soil water, Growing Season Rainfall (GSR) to date (122mm), and rainfall deciles from that date, except for the Farmer treatment. All treatments were sown with Granulock® Supreme Z fertiliser (7kg N/ha), and the N treatments applied as urea at GS30 (July 25).

Table 1. Nitrogen application rates (kg N/ha) top-dressed at GS30 (July 25) for the nitrogen rate trials on the low N site (West) and high N site (East).

Treatment	Nitrogen application rate top-dressed @ GS30 (kg N/ha)	
	Low N Site (West)	High N Site (East)
Nil	0	0
Farmer/Gut Feel	36	36
French and Schultz	173	104
Sadras and Angus	237	167
Yield Prophet® Decile 1	71	0
Yield Prophet® Decile 2-3	140	30
Yield Prophet® Decile 4-7	217	98
Yield Prophet® Decile 8-9	251	162
Yield Prophet® Decile 10	259	171

The third trial conducted only at the low N site examined the effect of different timings of urea applications on wheat yield and quality (Table 2). Each timing was applied at GS30 (July 25) and GS37 (August 27), 7-14 days before the crop reached the targeted growth stage (GS31, GS39). The trial received rainfall in the next seven days to wash the urea into the soil profile (GS30: 7mm, GS37: 6mm). Each treatment received a total of 123kg N/ha as top-dressed urea only. No Granulock® Supreme Z was applied to this trial.

Table 2. Nitrogen application treatments used in the three trials.

Treatment	Nitrogen application rate (kg N/ha)		
	Broadcast before sowing	Top-dressed @ GS30	Top-dressed @ GS37
Nil	0	0	0
0% up front, 100% @ GS30	0	123	0
25% up front, 75% @ GS30	31	93	0
50% up front, 50% @ GS30	62	62	0
75% up front, 25% @ GS30	93	31	0
100% @ up front, 0% @ GS30	123	0	0
33% up front, 33% @ GS30, 33% @ GS37	41	41	41

All trials were assessed using biomass cuts at GS65 (flowering), tiller counts, yield and grain quality.

RESULTS AND INTERPRETATION

How does the rate of nitrogen applied affect yield?

There was a significant yield response to N applied at the low N site (West) up to 150kg N/ha (Figure 1). However, there was no significant difference in yield from adding 180-265kg N/ha as the dry spring limited yields because of moisture stress rather than N deficiency. Despite the lack of moisture, we saw no increase in screenings and no decrease in test weight or yield, which is typically associated with haying off. There was no yield response to applying N in the high N paddock (East) (Figure 1).

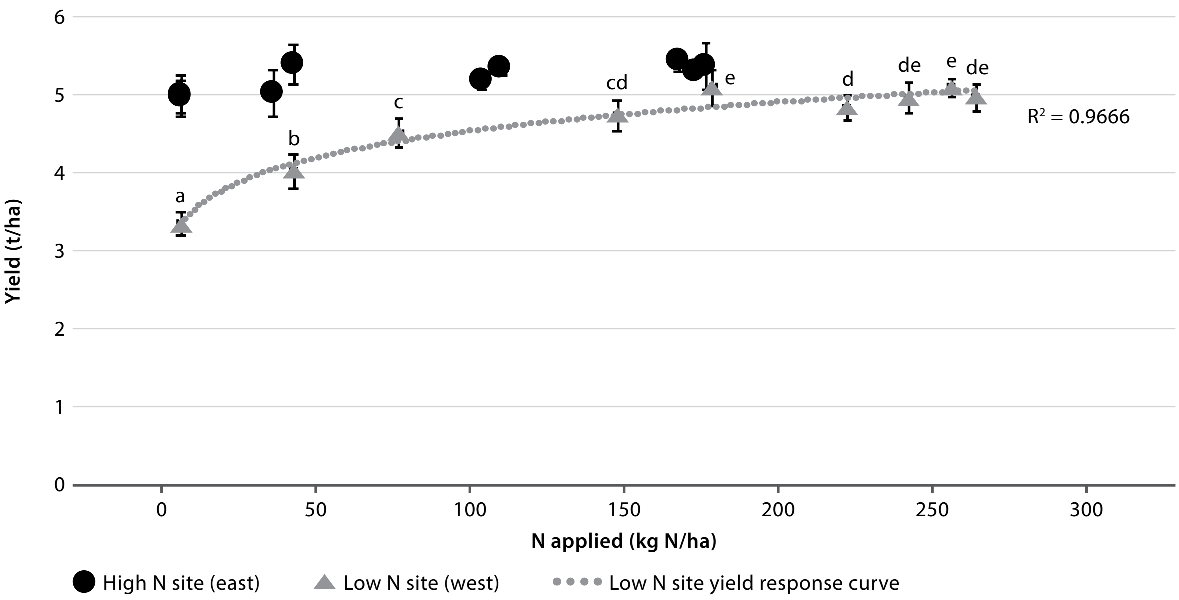

Figure 1. Yield (t/ha) response from applying nitrogen (kg N/ha) across the nitrogen rate Low N Trial ($p<0.001$, LSD=0.3, CV=3.9%) and the nitrogen rate High N trial ($p=0.107$, LSD=0.4, CV=5.1%) displayed with standard errors and least significant difference labels (Fisher's protected LSD, 95%). Low N site yield response power curve $y=2.6692x^{0.1132}$, $r^2=0.966$. Letters indicate significant difference.

How does the timing of nitrogen applications affect yield?

The timing trial at the low N site found a significant yield response (Figure 2) to timing of urea applications. There was a large yield penalty from applying no urea at all (approximately 1t/ha) and a smaller yield penalty (approximately 0.25t/ha) from delaying N application until GS30.

These differences in yield might be caused by the impact of timing on the number of tillers that developed, and hence, the number of grains that could be grown. The two treatments with no N applied at sowing, Nil applied treatment (270 tillers/m^2) and the 100 per cent at GS30 treatment (307 tillers/m^2), had significantly fewer tillers ($p=0.01$, LSD=52, cv=9.5%) than the 100 per cent at sowing (366 tillers/m^2).

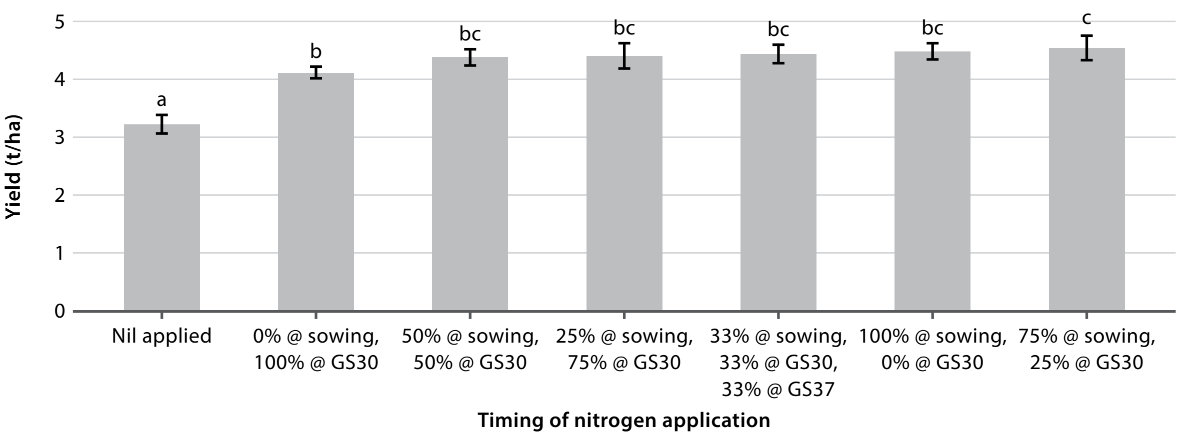

Figure 2. Yield (t/ha) from different application timings of 123kg N/ha on the low N (West) site ($p<0.001$, LSD=0.4, cv=6.4%) displayed with standard errors and least significant difference labels (Fisher's protected LSD, 95%). Letters indicate significant difference.

How does nitrogen strategy affect grain protein?

There was a significant response in grain protein to the amount of N applied at both the high N and low N sites (Figure 3). Overall, the high N site had higher grain protein than the low N site, even when similar amounts of N were applied. Both sites were quite low in protein, with only the four highest application rates (111-177kg N/ha) at the high N site achieving the 10.5 per cent protein required for APW. On the low N site, no treatments had grain protein higher than 9.8 per cent, despite up to 266kg N/ha being applied.

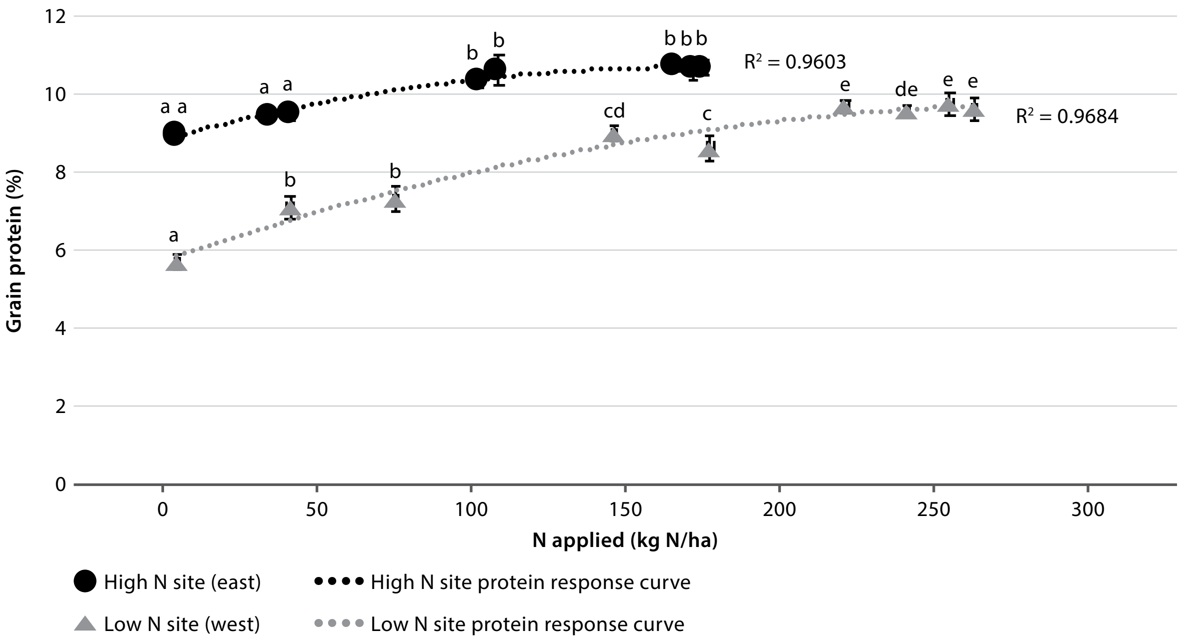

Figure 3. Grain protein (%) response from applying increasing nitrogen rates (kg N/ha) across the nitrogen rate Low N Trial ($p<0.001$, LSD=0.3, CV=4.9%) and the nitrogen rate High N trial ($p<0.001$, LSD=0.6, CV=4%) displayed with standard errors and least significant difference labels (Fisher's protected LSD, 95%). Low N site protein response polynomial curve $y=-4e^{05x2}+0.027x+5.6546$, $r^2=0.9684$. High N site protein response polynomial curve $y=-6e^{05x2}+0.0217x+8.7564$, $r^2=0.9903$. Letters indicate significant difference.

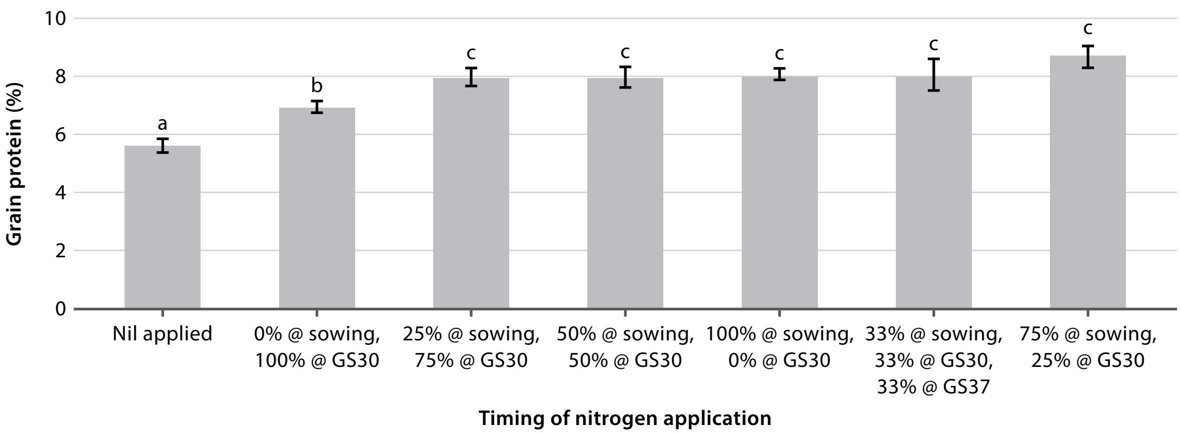

Figure 4. Grain protein (%) response to different timings of 123kg N/ha applied ($p<0.001$, LSD=0.8, CV=7.1%) displayed with standard errors and least significant difference labels (Fisher's protected LSD, 95%). Letters indicate significant difference.

The timing of N applications affected grain protein in a similar pattern to yield, with treatments that received N at sowing having significantly higher grain protein than those that did not (Figure 4). A late application of N at GS37 on top of previous applications at sowing and GS30, failed to significantly increase grain protein compared to treatments that also had urea applied at sowing and at GS30 (Figure 4). Grain protein was quite low across the trial, with all treatments making ASW standard due to low protein despite having 123kg N/ha applied.

One possible reason for grain protein being so low across the three trials, despite the large amounts of N applied, is that enough rain occurred to wash it into the surface soil, but not enough to wash it deep into the root zone. When the topsoil dried out in spring, the N at this depth became inaccessible to the crop.

How does N strategy affect biomass?

On the low N site, increasing N rates significantly increased crop biomass at GS65 (anthesis) (Figure 5). On the high N site, there was no significant response in crop biomass at GS65 to the amount of N applied (Figure 5).

There was no significant difference in biomass at GS65 due to the timing of N applications.

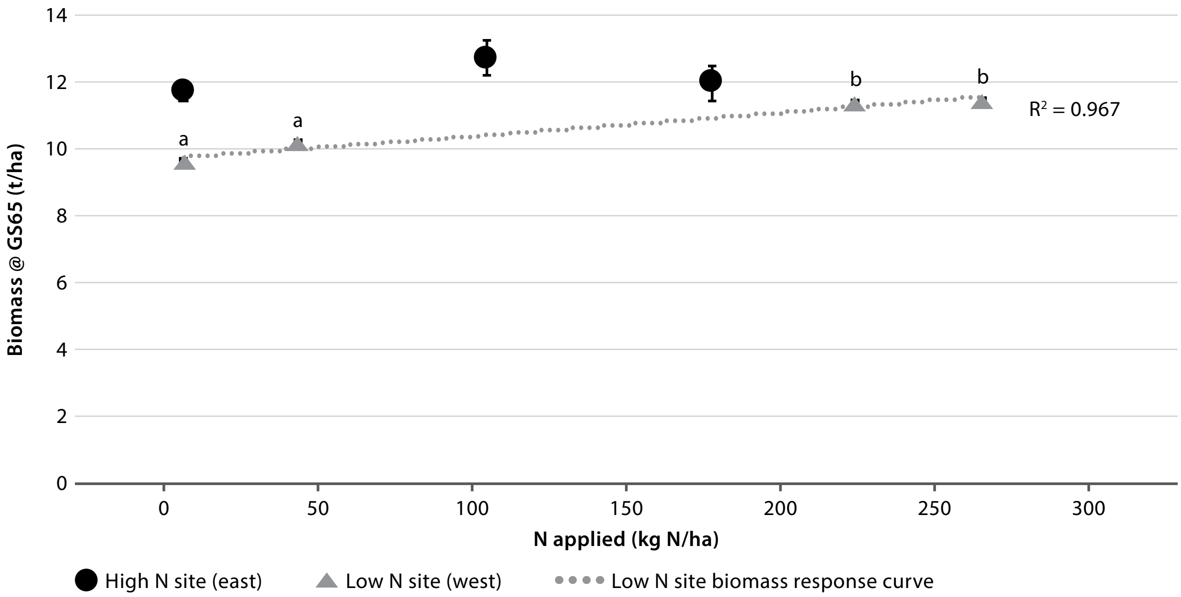

Figure 5. Crop biomass at anthesis (GS65) response from applying increasing nitrogen rates (kg N/ha) across the nitrogen rates Low N Trial (p=0.007, LSD=1.026, CV=6%) and the nitrogen rates High N trial (p=0.377, LSD=1.7, CV=8%) displayed with standard errors and least significant difference labels (Fisher's protected LSD, 95%). Low N site biomass linear response $y=9.6809e^{0.0007x}$, r^2=0.967. Letters indicate significant difference.

How accurate was each N strategy in achieving the predicted yield potential?

When the yield potentials were calculated on July 16, Karyrie had received 122mm (Decile 5) for the growing season. For the rest of the growing season, Karyrie received 74mm (Decile 1), finishing with a GSR of 197mm (Decile 3). To have a Decile 5 finish, which the French and Schultz and Sadras and Angus models assumed, Karyrie required 122mm of rain from July 17 to October 31, 48mm less than it recorded.

The dry spring reduced the estimated yield potential calculated in July, as the higher estimated yield potentials became moisture limited due to lack of rainfall, rather than a lack of N. This is reflected in the large reduction in actual yield potential, calculated in December when rainfall totals were known, compared to yield potential estimates calculated in July (Table 3 and Table 4).

All actual yield potentials, except for Sadras and Angus, underestimated the yield achieved at both trial sites by varying amounts. This might be due to underestimating the amount of stored soil water, which could have affected the Yield Prophet® calculations, and/or that the French and Schultz model was developed using older varieties with lower water use efficiency than Scepter. The good growing season (stored soil moisture, earlier than average break and cool temperatures in spring) may also have allowed for higher yields than suggested by rainfall alone. Sadras and Angus on the high N site was the only treatment where actual yield potential matched actual yield (Table 3), but on the low N site it overestimated yield potential by 0.6t/ha (Table 4).

The yield potential estimates calculated in July, when N decisions were being made, varied greatly in how close they were to predicting actual yield. French and Schultz (Decile 5) was the closest, followed by Yield Prophet® Decile 2-3. The French and Schultz result was a 'fluke' because rainfall input into the model was higher than Karyrie received, so it should have given an inaccurate result. The Yield Prophet® Decile 2-3 came close to predicting yield because it matched how much rainfall was received in the growing season. While predicting exact rainfall from July to October is difficult, forecasting models become their most accurate around July. Consulting forecasts at this time can provide better information about the likelihood of a wet or dry spring and help make decisions about N application.

Table 3. Estimated yield potential calculated in July (assuming Decile 5 finish/122mm) (t/ha), actual yield potential calculated in December (with actual rainfall 74mm/Decile 1 finish) (t/ha), and actual yield harvested (t/ha) for each treatment in the rate trial on the High N (East) site. Yield Prophet® estimates provided without frost and heat effects.

High N (East) site treatments	Estimated yield potential – July (t/ha)	Actual yield potential – December (t/ha)	Achieved yield (t/ha)
Sadras and Angus	6.3	5.3	5.3
French and Schultz	4.8	3.8	5.3
Yield Prophet® Decile 4-7	6.1	3.3	5.1
Yield Prophet® Decile 8-9	7.9	3.2	5.4
Yield Prophet® Decile 10	8.2	3.2	5.3
Nil	3.6	3.2	4.9
Yield Prophet® Decile 1	2.8	3.2	4.9
Yield Prophet® Decile 2-3	4.2	3.1	5.0
Farmer	-	-	5.4

Table 4. Estimated yield potential calculated in July (assuming Decile 5 finish/122mm) (t/ha), actual yield potential calculated in December (with actual rainfall 74mm/Decile 1 finish) (t/ha), and actual yield harvested (t/ha) for each treatment in the rate trial on the Low N (West) site. Yield Prophet® estimates provided without frost and heat effects.

Low N (West) site treatments	Estimated yield potential – July (t/ha)	Actual yield potential – December (t/ha)	Achieved yield (t/ha)
Sadras and Angus	6.6	5.5	4.9
Yield Prophet® Decile 8-9	7.7	4.1	5.1
YP Decile 10	8	4.1	4.9
French and Schultz	5	4	5.0
Yield Prophet® Decile 4-7	6.8	3.9	4.8
Yield Prophet®Decile 2-3	4.9	3.3	4.7
Yield Prophet® Decile 1	3.1	1.6	4.5
Nil	1.4	1.6	3.3
Farmer	-	-	3.9

COMMERCIAL PRACTICE

Crop rotations, fertiliser history and organic matter removal (grain, hay, straw) can all alter how much N is stored in the soil. With the diverse rotations across the Mallee and Wimmera, it would be common for two neighbouring paddocks to have different amounts of N stored in the soil, as occurred in this trial. It is important to understand how much N is stored in the soil to ensure yield and grain protein are not limited by N. The best way to understand starting N levels in each paddock is to conduct soil tests before sowing.

In low N paddocks with large amounts of starting soil moisture, applying some N at sowing, rather than waiting until GS30, will increase yield by ensuring that the crop has access to N early to promote tiller formation. This is especially beneficial in seasons such as 2019 with a dry spring, where the N in the top-soil may become inaccessible as it dries. It can also help to mitigate the risk of a lack of opportunities to apply urea at GS30. When applying N at sowing, be sure to check seed placement is not too close to the applied N to prevent fertiliser burn.

Identifying paddocks with low soil N will determine which paddocks should show the highest likely response to applying N. In this trial, wheat yield increased by 1.4t/ha on the low N site by adding up to 150kg N/ha. The increase in yields from applying up to 77kg N/ha (Figure 6) boosted income per hectare (after deducting urea and spreading costs). These gains are 'low hanging fruit', where applying N should provide higher returns on investment due to the greater increases in yield, rather than applying urea in paddocks with high starting N.

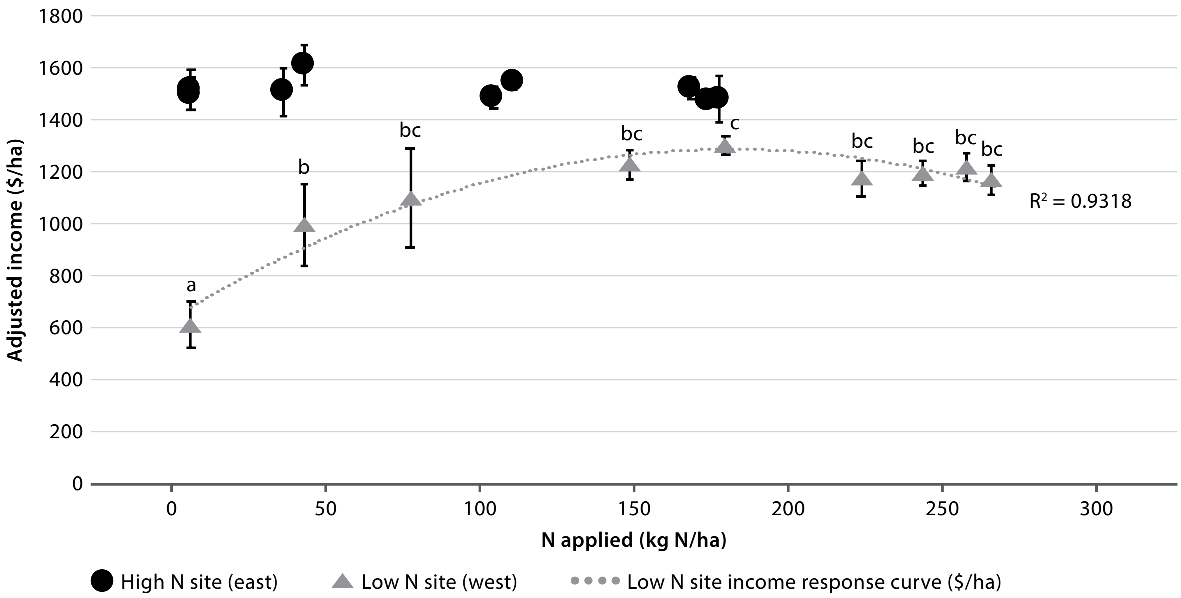

Figure 6. Income remaining after nitrogen costs deducted (Urea $500/t, spreading=$5/ha) across the N Management Low N Trial (p<0.001, LSD=259, CV=16%) and the N Management High N trial (p=NS) displayed with standard errors and least significant difference labels (Fisher's protected LSD, 95%). Low N site biomass polynomial response curve y=-0.0197x²+7.1551x+633.52, r²=0.9318. Letters indicate significant difference.

Even without an increase in yield (Figure 1) or income (Figure 6), high N paddocks should still have N applied and soil N levels monitored, if the starting conditions are very favourable. While a yield response to top-dressing urea was not seen on the high N site in this trial, the high N site had higher yields than the low N site. Where both sites had 43kg N/ha applied, the high N site yielded 1.16t/ha more than the low N site with 2.4 per cent more protein. This highlights the benefits of having higher starting N on similar soil types with similar moisture and low disease levels. It also shows the risk of depleting high N paddocks over time, by exporting more N from the soil in grain and hay than is applied as fertiliser or fixed by legumes.

Furthermore, it has been shown that in low rainfall areas with heavier soil types that N not used in the season it was applied will be available in the soil in future seasons (Murray and Hunt 2019). While there was no added yield response to applying urea on the high N site or above 150kg N/ha on the low N site, the applied N should still be available in the 2020 season. It has also been shown that maintaining N in the soil, rather than depleting it from the soil is equally profitable in the long term, compared to matching inputs to seasonal yield potential (Murray and Hunt 2019). Similarly, in other years where yields are limited by a lack of rain, applying urea should not be seen as lost money, but a 'deposit' towards higher yields in the next season.

Finally, until there is a perfect growing season forecast available from March each year, applying N will never be risk free. The best way to minimise the risks is to make an informed decision through understanding the pre-sowing stored soil water and starting soil N available, and then applying N to reach that yield potential. While yield potential estimates will be affected by weather conditions other than rainfall, making a calculated decision is most likely to lead to a profitable result.

REFERENCES

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