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Should high nitrogen rates be applied to boost cereal protein in the Esperance Port Zone?

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Key messages

- Grower practice N rates at both sites were the most economical
- Applying higher rates of N to maintain or increase protein was not profitable if yield did not also increase
- Grain markets should be watched in case higher quality grades fetch significantly higher prices
- Increased nitrogen can lead to increased incidence of powdery mildew if not controlled early in the season.

Aim

To optimise cereal protein by better understanding response to high nitrogen rates in each season, through demonstration trials while also better understanding disease response.

Background

Growers in the Esperance port zone (EPZ) are concerned about decreasing grain protein levels as their cereal yields increase. Protein is one of the most important quality traits of both wheat and barley in determining the end use of grain (Williams et al., 2019). Williams et al. (2019) also notes that protein levels of Australian wheat have been decreasing over the past decade, likely driven by increasing yields. Western Australian wheat has produced the lowest protein in Australia in 60% of years since 1999/00 (Williams et al., 2019). Similarly, barley protein in Western Australia has also been shown to be declining with much of the grain produced in WA not meeting protein standards for malting requirements (Curry et al., 2019).

Protein in cereals is known to increase if good nitrogen supply is available post stem-elongation. Early supply of nitrogen will increase vegetative growth and yield potential, and excess nitrogen or later applied nitrogen is more likely to contribute to protein (Anderson & Garlinge, 2000). More growers in the EPZ are opting for continual cropping with limited legume options so there is a greater reliance on nitrogen fertiliser.

Weather and soil conditions must be conducive for nitrogen (N) fertiliser to be converted into grain protein. Research into the relationship of timing and rate of nitrogen fertiliser application on grain protein has shown consistent increases in grain protein from applying nitrogen later in the season, such as at stem elongation (Curry et al., 2019).

Decision making on the optimal rate and timing of nitrogen application is difficult given variability of likely seasonal climate conditions. Hindsight and experience can be an important tool in growers' decision making, however, there are some decision support tools that can help such as 'Select Your Nitrogen' and yield forecasting models such as

CliMate App and the ‘Potential Yield Tool’ by DPIRD (Dept of Ag, 2003) (Australian CliMate, 2020). ‘Select Your Nitrogen’ is a model that allows users to input their own paddock management information and to estimate yield and protein outputs. The CliMate App uses climate data for predictions on many seasonal questions including potential yield.

Powdery mildew and yellow leaf spot (YLS) are two of the main wheat foliar diseases evident in the EPZ. Conditions that favour powdery mildew infection include mild temperatures, dense crop canopies, good soil moisture and high nitrogen nutrition (DPIRD, 2020). Conversely, nitrogen deficient wheat crops have been shown to be more vulnerable to infection of YLS (DPIRD, 2018).

In 2019 (Pearse, 2019) demonstrations undertaken at three different locations (Grass Patch, Neridup and Beaumont) showed that higher economic returns only occurred from increasing yield. Increasing protein only, to achieve higher grades, did not result in better economic returns. 2019 was a very dry year (Decile 1) and undertaking these trials again in 2020 was important to understand this relationship in a potentially different rainfall decile year, rather than rely on modelled data only.

Demonstration trials were implemented at two locations of different soil types and paddock preparation. The aim was to better understand how applying different rates of N impacted profitability and protein levels of wheat and how this impacts disease incidence.

Method

Two sites were set up in Neridup in 2020, where three nitrogen rate treatments were applied in strips at the grower scale, replicated twice (Figure 1).

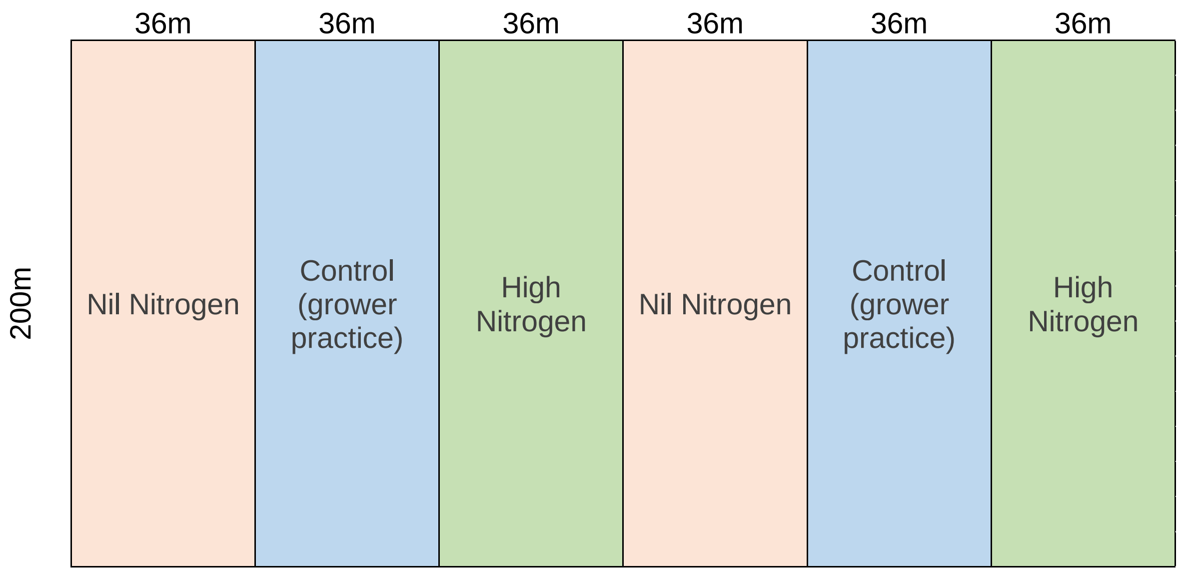

Figure 1. Trial layout showing treatments.

Both sites were sown to Scepter wheat. The strips were 36m wide and 200m long. Treatments varied according to the grower’s nitrogen management plan for the paddock they were located in and are outlined in Table 1. Nitrogen applied at seeding did not vary between treatments.

Table 1. Crop type, variety and nitrogen treatment details of each site in 2020. Treatments were adjusted to suit the growing environment of the trial location.

Site	Crop (Variety)	Date sown	Treatment	Nitrogen application			Date N applied
				Urea kg/ha	UAN L/ha	Total kgN/ha	
Site 1	**Wheat (Scepter)** (0 kg/ha N @ seeding)	2/5/2020	1 – Nil	-	0	0	9/7/2020
			2 - Control (Grower practice)	-	100	42	
			3 – High	-	200	84	
Site 2	**Wheat (Scepter)** (31.5 kg/ha N @ seeding)	15/5/2020	1 – Nil	0	0	31.5	Urea – 9/7/2020 UAN – 20/7/2020
			2 - Control (Grower practice)	100	50	96.7	
			3 - High	200	100	162	

Site one was spader-seeded with no nitrogen applied at seeding. Site two was sown using a conventional knife point seeder with 50 L/ha of UAN and 100 kg/ha of K-till plus applied at seeding (31.5kgN/ha).

Soil samples were taken to characterise starting soil nitrogen and organic carbon to aid in modelling. When the crop was fully ripe (GS89), whole above-ground biomass cuts were sampled at three locations per strip, at least 60m apart down the length of the strip. Cuts were dried and processed to assess biomass and yield components.

Harvest data was collected by SEPWA Trials Coordinator Bill Sharp using the SEPWA weigh trailer. Grain samples were collected and analysed for quality in an Infratec™ NOVA.

Wheat and barley prices are based on average 2020/21 season prices obtained from local marketers (Table 2).

Table 2**.** Average prices obtained for different grade classifications in the 2020/21 season. Source: CBH

Crop	Grade	Price $	Protein limit %
Wheat	APW1	314	≥10.5
	APW2	306	≥10.0
	ASW	299	No limit

Wheat and barley classifications were made using CBH receival standards (CBH Group 2019/20). The CliMate App and 'Select Your Nitrogen' models were used to assess the impact of the different nitrogen rates in different rainfall decile years.

Disease scoring

Three transects were set up down the length of the trial, at least 60 m apart, and disease scores were given on 10 tillers per treatment along these transects. Scores were done twice in the season at site 1, on 27 August at early stem elongation (time point 1) and the second at flowering/grain fill on 6 October (time point 2). Leaf area diseased (LAD%) was scored at time point 1 for powdery mildew (PM) and yellow leaf spot (YLS) on the flag and F-1 leaves. Difficulty in distinguishing individual disease symptoms at time point 2 meant leaves were scored for chlorotic symptoms and necrotic area together and disease not distinguished between PM or YLS. Green leaf area (GLA) was also scored at time point 2 on the flag and F-1 leaves.

At site 2 LAD (on the head and flag leaf) and GLA (on flag leaf) scores were done at a single time point on 14 October. Scores were transformed using ArcSin (squareroot mean score %) before analysing with ANOVA in Genstat.

Results

The 2020 growing season in Neridup finished as a decile 2 year for rainfall, with 251.5mm of growing season rainfall (GSR). There were strong wind gusts on 6 May that resulted in moderate furrow fill at Site 1 which had recently been spaded but this did not impact crop establishment. There were no other major weather events.

Site 1 results

Samples collected from the header and put through the weigh trailer showed yields ranged from 3.4–4.0t/ha, with the lowest yield attributed to the lowest nitrogen rate (Table 3).

Table 3. Yield, protein, grain grade, and economic return of the different nitrogen treatments of the 2020 trials results and of modelled outputs in a decile 1, 5 and 9 rainfall year at Site 1.

	Treatment		Yield t/ha	Protein %	Grade	Gross return $	N cost $	Net return of N cost $	ROI %
	UAN L/ha	Total N kg/ha							
2020 trial results	0	0	3.4	7.8	ASW1	$1,004	0		
	100	42	4.0	7.4	ASW1	$1,183	50	$129	258
	200	84	3.9	8.4	ASW1	$1,157	100	-$126	-126
Modelled results									
Decile 1 year	0	0	1.4	8.1	ASW1	$407	0		
	100	42	2.3	8.5	ASW1	$697	50	$240	480
	200	84	2.8	9.3	ASW1	$834	100	$38	38
Decile 5 year	0	0	1.4	8.1	ASW1	$428	0		
	100	42	2.6	8.3	ASW1	$789	50	$312	624
	200	84	3.4	8.6	ASW1	$1,029	100	$139	139
Decile 9 year	0	0	1.5	8.1	ASW1	$443	0		
	100	42	2.9	8.1	ASW1	$867	50	$375	749
	200	84	4.0	8.3	ASW1	$1,202	100	$235	235

Protein ranged between 7.8–8.4%, all treatments achieved a grade of ASW1. Return on investment (ROI) analysis indicated that the grower practice treatment of applying 100L/ha of UAN was the most economical with a ROI of 258%. This is due to yields increasing to 4.0t/ha in this treatment, from 3.4t/ha in the nil N treatment. Applying the higher rate of N (200L/ha of UAN) was not economical as there was no increase in yield to offset the cost of the extra N fertiliser, this treatment resulted in a ROI of -126%.

Analysis of biomass cuts into yield components also indicated that, there was no statistical difference in yield between the N treatments (Table 4). Where there was any N applied in season there was a significant increase in the number of tillers on each plant. There was no difference in the number of grains per head between treatments, however the weight of each grain was higher in the Nil N treatment plots. This resulted in no change in yield between the treatments. This analysis indicates that there was an insufficient amount of N at grain fill for higher tillering plants to increase grain weight. An additional application of N later in the season could have boosted yield further and resulted in a significantly increased yield in the N top up treatments.

Table 4. Yield component analysis from biomass cuts taken at harvest ripe at site 1. (Letters indicate significant differences between treatment when $P \leq 0.05$. Where no lettering the difference was not significant.)

Treatment		No. tillers m²	Grains per head	1000 grain wt (g)	Harvest index	Yield t/ha
UAN L/ha	Total N kg/ha					
0	0	329.8^{a}	35	42.16^{c}	0.45	4.8
100	42	439.6^{b}	33	37.45^{b}	0.42	5.4
200	84	449.2^{b}	37	32.77^{a}	0.44	5.5

Modelled results from decile 1, 5, and 9 years show that grower practice rate of N (100L/ha UAN) is always the most economical (Table 3). In a decile 1 year, modelled results indicate an increase in yield of 0.9t/ha could occur when grower practice N is applied compared to Nil N, with a further 0.5t/ha yield increase when 200L/ha UAN is applied (Table 3). While there is an increase in protein when N is applied in-season all treatments would still only achieve ASW1. Protein increases from 8.1% in the nil treatment to 9.3% in the high N treatment (200L/ha UAN). These results still showed that the most profitable N rate would be the grower practice rate with a ROI of 480% compared to 38% in the high N treatment.

In a decile 5 year modelled results also showed an increase in yield could be achieved with a jump of 1.2 t/ha from the Nil treatment to grower practice and then a further 0.8t/ha to the high N treatment (Table 3). Protein remained low with all treatments achieving ASW1 and ranging from 8.1% (Nil) to 8.6% (high). Due to the increased yield there was a further increase in the ROI in a decile 5 year with a return of 624% when grower practice rates are applied and 139% when high rates are applied (Table 3).

Similarly, modelled results from a decile 9 year showed increases in yield as N rate increased but limited increase in protein. When nil N is applied yield would be 1.5t/ha, grower practice N treatment had a yield of 2.9t/ha and high N treatment a yield of 4.0t/ha. Protein ranged between 8.1–8.3 % (Table 3). The best ROI of 749% resulted from the grower practice N treatment.

Figure 2 indicates optimum net return of N cost occurs with the grower practice treatment, in both trial data and all modelled decile years. Figure 2a indicates that trial yields plateaued as N rate was increased, however modelled data showed yield to be further increasing. Despite the increasing modelled yields Figure 2b shows that net return of N costs ($) peak at the grower practice N rate and decrease when further N is applied.

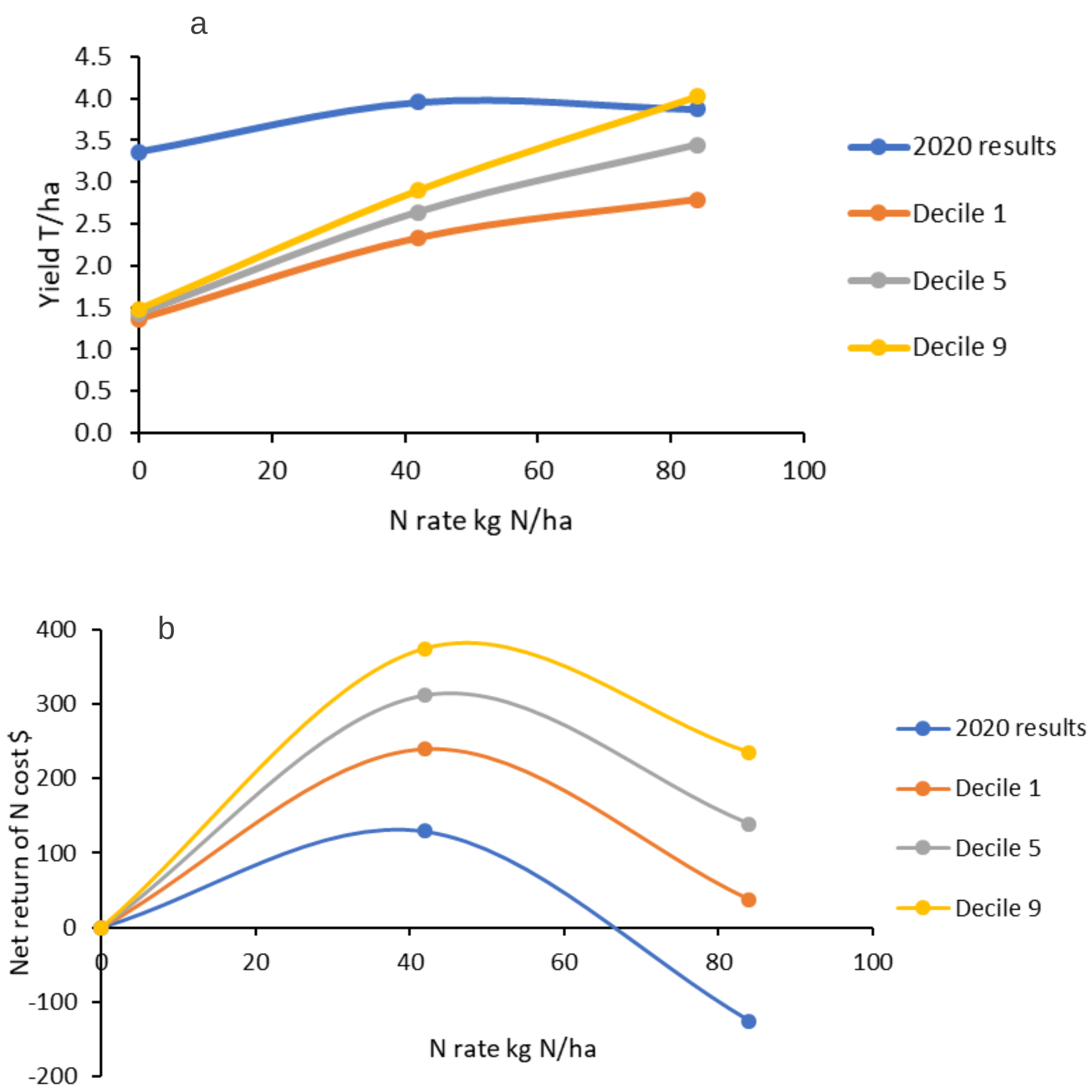

Figure 2. Graphs showing yield response curves (a) and the net benefit of N application (b) to in-season N rate of trial results and modelled results for decile 1, 5 and 9 years at site 1 in Neridup.

Site 2 results

Yield increased by 0.7t/ha when the grower practice N rate was applied (5.3t/ha) and increased by 1t/ha with the high N rate (5.6t/ha) compared to no N (4.6 t/ha) (Table 5). Protein increased from 8.9% (Nil N) to 10.8%, achieving a grade of APW1 with the high N rate. The grower practice N rate treatment had an increase of 0.9% in protein compared to the nil treatment, increasing protein to 9.8%. This does not change the grade of the wheat and both grower practice and the nil N would be received as ASW1. ROI for the 2020 results was highest when grower practice N rate was applied resulting in a ROI of 139%. This indicates that although a higher grade was achieved with the higher N rate, price difference between grades is not enough to compensate for the higher cost of the extra N applied (Table 5).

Table 5. Yield, protein, grain grade, and economic return of the different nitrogen treatments of the 2020 trials and of modelled outputs in a decile 1, 5 and 9 rainfall year at Site 2.

	Treatment			Yield t/ha	Protein %	Grade	Gross return $	N cost $	Net return of N cost $	ROI %
	Urea kg/ha	**UAN L/ha**	**Total N kg/ha**							
2020 trial results	0	0	31.5	4.6	8.9	ASW1	$1,377	0		
	100	50	96.7	5.3	9.8	ASW1	$1,579	84	$117	139
	200	100	161.9	5.6	10.8	APW1	$1,766	168	$19	11
Modelled results										
Decile 1 year	0	0	31.5	2.0	8.3	ASW1	$589	0		
	100	50	96.7	2.8	9.4	ASW1	$843	84	$170	203
	200	100	161.9	2.9	11.2	APW1	$898	168	-$113	-67
Decile 5 year	0	0	31.5	2.2	8.2	ASW1	$646	0		
	100	50	96.7	3.5	8.7	ASW1	$1,052	84	$323	384
	200	100	161.9	4.0	9.7	ASW1	$1,208	168	-$13	-7
Decile 9 year	0	0	31.5	2.3	8.1	ASW1	$688	0		
	100	50	96.7	4.2	8.3	ASW1	$1,241	84	$469	559
	200	100	161.9	5.3	8.7	ASW1	$1,585	168	$176	105

Analysis of biomass cuts into yield components indicates that an increase in yield occurs when any N is applied in season, but there is no difference in yields between the two in-season treatments grower practice (100kg/ha) and high N (200kg/ha) (Table 6). This increase in yield comes from both an increase in the number of tillers and the number of grains per head. Statistically there is no difference in the weight of the grain and therefore, where there are more tillers and grains per head, there is more yield. This analysis shows that there was sufficient nitrogen left in the soil for the plants to utilise during grain fill.

Table 6**.** Yield component analysis from biomass cuts taken at harvest ripe at Site 2. (Letters indicate significant differences between treatment when P ≤ 0.05. Where no lettering the difference was NS)

Treatment			**No. tillers m²**	**Grains per head**	**1000 grain wt (g)**	**Harvest index**	**Yield t/ha**
Urea kg/ha	**UAN L/ha**	**Total N kg/ha**					
0	0	31.5	287.2[a]	32[a]	48.6	0.43	4.3[a]
100	50	96.7	353.8[b]	39[b]	41.2	0.44	5.7[b]
200	100	161.9	372.3[b]	41[b]	40.1	0.45	6.1[b]

Modelled results from decile 1, 5 and 9 years also indicate that the best ROI was achieved when grower practice amount of N is applied (Table 5). Modelled results from a decile 1 year show that applying the grower practice rate of N increases yields by up to 0.8 t/ha (to 2.8 t/ha) and protein by 0.9%. This increase in protein does not improve the receival grade and the wheat remains as ASW1. ROI is high when grower practice N rate is applied, at 203%, and this is due to the increase in yield. When the high N rate is applied yield remains similar to the grower practice N rate, at 2.9 t/ha. Protein increases to 11.2% and pushes the grain into APW1 grade. This improvement in grade does not improve economic returns with a ROI of -67% (Table 5). This shows that in a water limiting year, such as a decile 1 year, once peak yield is achieved available N will increase protein however not necessarily increase economic returns.

Decile 5 modelled data indicates that while yield and protein increases as N rate increases there is no economic benefit to apply more N than the grower practice N rate. Protein does increase with every increase in N rate, however, does not increase enough to improve the wheats grade from ASW1 (Table 5). In a decile 9 rainfall year yield increased by 3 t/ha, from 2.3 t/ha in the nil treatment to 5.3 t/ha, when the highest N rate is applied. Protein increased by only 0.6% (Table 5).

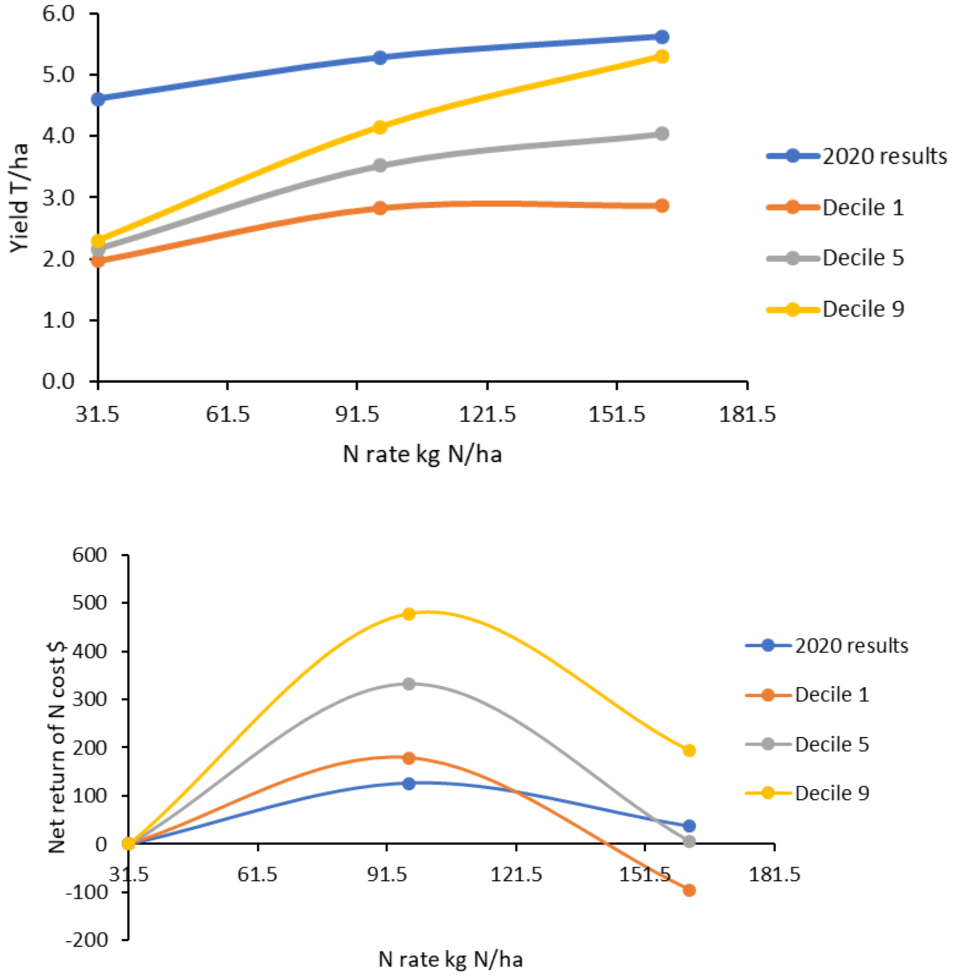

Figure 3. Graphs showing yield response curves (a) and the net benefit of N application (b) to in-season N rate of trial results and modelled results for decile 1, 5 and 9 years at site 2 in Neridup.

The best ROI, again, resulted from the grower practice N rate at 559%. Even higher rates of N would need to be applied in season than the high N rate treatment when in a high decile rainfall year to further increase protein. Modelling in Figure 3a indicates there is still potential to further increase yield as Figure 3a shows that yield does not plateau with any N rate. Figure 3b indicates that the optimum net return of N cost is when the grower practice amount of N is applied in all decile years.

Disease results

At site 1 increasing nitrogen rates created conditions that favoured powdery mildew infection yet was more effective at preserving green leaf area than when low nitrogen was applied. The opposite was true for YLS where there were more symptoms under low nitrogen compared to grower and high nitrogen rates (Table 7).

Table 7. LAD and GLA scored at Site 1 at two time points, early stem elongation (Time 1) and flowering early grain fill (Time 2). (Letters indicate significant differences between treatments, P-value ≤0.05. *Arc transformed analysis results)

N rate	Time 1				Time 2			
	Powdery mildew LAD%		YLS LAD%		LAD%		GLA%	
	Flag	F-1	Flag	F-1	Head	Flag	Flag	F-1
Nil	0.3[a]	0.1[a]	0.9[b]	2.8[b]	11.5[a]	13.4[b]	58.9[a]	35.5
Grower rate	3.1[b]	0.5[b]	0.2[a]	0.9[a]	24.1[b]	11.3[a]	67.2[b]	40.9
High rate	4.5[c]	0.5[b]	0.1[a]	0.3[a]	37.7[c]	14.0[b]	66.5[b]	33.2
P value*	<0.001	<0.001	<0.001	<0.001	<0.001	0.009	0.005	0.211

By flowering/grain fill disease symptoms were difficult to distinguish between powdery mildew and glume blotch (caused by *P. nodorum*) so leaves were scored as combined percent area symptomatic. There was more area with disease symptoms on wheat heads with increasing nitrogen rates. However, there was greater green leaf area on the flag leaf at this time point when grower and high rates of nitrogen was applied compared to the nil (Table 7).

Table 8. LAD (leaf area of disease) and GLA (green leaf area) scored at site 2 at a single time point for nil, grower and high N rates. (Letters indicate significant differences between treatments, P-value ≤0.05. *Arc transformed analysis results)

Similar results were also seen at site 2 where there was significantly greater area diseased on wheat heads with increasing nitrogen rates. However, there was no nitrogen effect on disease symptoms and green leaf area on the flag leaf (Table 8).

N rate	LAD%		GLA%
	Head	Flag	Flag
Nil	5.7[a]	8.9	67.2
Grower rate	10.2[b]	8.3	70.1
High rate	14.6[c]	9.6	72.7
P-value*	0.001	0.512	0.292

Conclusion

Results from these two sites indicate that economic return from increased N rate only occurs when yield is increased. Both sites showed limited increases in protein hence wheat mostly fetched the same price between N treatments. If protein was further increased there is a potential for better economic returns, however in a similar 2019 study (Pearse, 2019) this was shown not to be the case. In this study treatments that achieved higher grades often did not have higher yields and, where market prices were tight, this did not result in better economic returns.

This data shows that currently there is no benefit from applying higher rates of N than growers are already applying. Grower knowledge and experience has been proven to pay off. It is important to keep an eye on markets for changes in price differentiation between grades as any increase in the price premium for higher proteins could make it beneficial to apply more nitrogen. Thorough economic analysis should be done before this is put into practice.

Furthermore, growers should be aware that with higher nitrogen rates and better nutrition comes risk of increased powdery mildew infection. This could further impact economically with a need for increased fungicide application and potentially decreased yield. While there was increased YLS incidence in low N plots at this trial this had less of an impact than powdery mildew did later in the season.

References

Anderson, W.K and Garlinge, J.R (2000). *The Wheat Book, Principles and Practice.* Perth: Department of Agriculture, Western Australia.

Australian CliMate (2020). *Potential Yield?* Retrieved from https://climateapp.net.au/A09_WhatYield

CBH Group (2019). *Operations Harvest Guide 2018-20, A guide for delivering grain to CBH Group receival sites*. CBH Group, Western Australia.

Curry, J, Paynter, B, Hansch, S and Van Burgel, A (2019). *Increased grain protein with delayed applications of fertiliser nitrogen*. 2020 Agronomy Australia Proceedings. http://agronomyaustraliaproceedings.org/index.php/2019/48-2019/768-2019-crop-nutrition

DPIRD (2020), *Managing powdery mildew in wheat.*

DPIRD (2018), *Managing yellow spot and septora nodorum blotch in wheat.*

Department of Agriculture, Government of Western Australia (2003). *Select Your Nitrogen.*

Pearse, E (2019) Managing N applications in undertain seasons. Online Farm trials https://www.farmtrials.com.au/trial/31598

Williams, R, Darragh, L, Mathews, L, Southan, M (2019). *Gains in Grains: Is Australia Producing the Most Profitable Quality of Wheat*. GrainGrowers Australia.

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Important disclaimer