Closing the yield gap through better matching nitrogen supply to yield potential

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EPAG Research

Location
Cockaleechie
Rainfall
Av. Annual: 422 mm
Av. GSR: 341 mm
2022 Total: 596 mm
2022 GSR: 395 mm
Paddock History
2019: Wheat
2020: Canola
2019: Wheat

Location
Lock
Rainfall
Av. Annual: 387 mm
Av. GSR: 292 mm
2022 Total: 487 mm
2022 GSR: 292 mm
Paddock History
2019: Wheat
2020: Vetch
2019: Canola

Location
Minnipa
Rainfall
Av. Annual: 280 mm
Av. GSR: 223 mm
2022 Total: 487 mm
2022 GSR: 300 mm
Paddock History
2019: Lentils
2020: Wheat
2019: Canola

Key messages

- **The application of nitrogen (N) can play a critical role in attaining yield potential across all rainfall zones on the Eyre Peninsula, particularly in above average rainfall seasons. However, determining the quantity to add and where across a landscape with varying soil types can be difficult.**
- **Utilising pre-seeding soil tests, understanding the productive capacity of varying soil types and improved knowledge of N mineralization rates can result in nitrogen applications being better tailored to soil type and environment.**
- **Optimising N applications across variable soil types can increase yields and/or save inputs and increase margins.**
- **Starting N levels will heavily influence response to N. Knowledge of this should influence decision making.**

Why do the trial?

'Yield gap' is the difference between actual achieved crop yield and true potential yield (limited by rainfall and other environmental conditions). While many factors contribute to the yield gap, the largest contributor across all Australian rainfall zones is nitrogen deficiency (Hunt *et al*., 2021). Sub-optimal nitrogen use can contribute up to 60% lower yields than the true potential (Hochman *et al.*, 2018).

The well above average summer rainfall that fell between crop maturity 2021 and early 2022, coupled with effective summer weed control programs, saw many paddocks across the Eyre Peninsula commence the 2022 growing season with near full soil moisture profiles. Understanding how this stored water can translate into increased yield required understanding of soil characteristics, nitrogen levels and plant demand.

Getting the balance between application of nitrogen to capitalise on opportunity, but not over-spending when the result is far from assured, is incredibly difficult. The question then arose of how to increase confidence in nitrogen decisions, bring the yield gap closer, all the while taking economics into consideration? Trials were set up with the aim of reducing the gap between potential and realised yield through increased knowledge of soil water holding characteristics, starting nitrogen levels, and more informed knowledge of nitrogen mineralisation rates.

How was it done?

Three trial sites were chosen, each with duplicated trials in areas in the paddock that had historically performed better and poorer. Minnipa, Lock and Cockaleechie were chosen to represent the varying rainfall and production systems across the Eyre Peninsula. Better and poorer areas were chosen based on previous yield data and soil type, indicating consistency in high or low historical yields.

Trials were complete randomised block designs with four replicates. An additional two rows or eight plots were planted for deep soil N monitoring throughout the season, which were not harvested for yield due to the destructive manner of sampling.

Minnipa

The Minnipa site had a 1 t/ha canola stubble, on a sandy loam soil type. The good site was a consistently high performing area of the paddock, a well-draining soil which holds and responds to moisture and nitrogen well, resulting in high yields. The poor site also had high starting nitrogen and moisture down the soil profile, yet this was not accessible to the crop as boron levels became toxic around 60 cm, confirmed by soil characterisations at the start of the season.

Lock

The Lock trial was sown into a 1.5 t/ha canola stubble on a sandy loam. Areas of lower productivity usually correlated with shallow rock. The good trial site was a sandy loam over sandy clay loam, historically a highly productive part of the paddock. The poor site was a clay loam, in a rocky area, with a hard limestone layer at 40-50 cm. Highly calcareous shale/sand continued at depth.

Cockaleechie

The Cockaleechie good site soil type was clay loam over medium clay on a 6 t/ha wheat stubble. The trial in the high yielding zone at Cockaleechie was different to the Lock and Minnipa sites. This trial was a bigger trial, part of a BCG (Birchip Cropping Group) N Banking project. The ideas of targeting yield and inputs based on projected rainfall and deep N testing were the same between trials, with a slightly different layout. The Cockaleechie poor site was a sandy loam over clay.

Plots were all sown with Scepter wheat. Minnipa, Lock and Cockaleechie were sown on 10, 11 and 12 May respectively. Herbicide, fungicide and insecticide were applied as per district practice. All nitrogen was applied as top-dressed urea, hand spread. All plots received 14 kg/ha of nitrogen at sowing. The remaining nitrogen was applied on 17 June for Minnipa and Lock, then 27 June for Cockaleechie. The late application treatments were applied on 22 and 23 August. Biomass cuts of all treatments were taken at flowering as an indicator of N response.

Deep N samples were taken over the season to monitor nitrogen use and mineralisation. Pre-seeding, multiple in season and harvest cores were taken at all sites to monitor N. These plots only received 14 kg N at seeding.

Start of seeding plant available soil moisture levels were used in combination with historical rainfall to make approximate yield targets. From this target nitrogen requirements were calculated, using the rule of thumb of 40 kg/ha N per 1 tonne of wheat yield. Mineralisation estimates and starting soil nitrogen (0-60 cm) were taken from this number to quantify the remaining nitrogen requirement to reach the desired yield target.

Treatments

Each trial had eight N rate treatments. The goal of treatments was to match nitrogen application to a range of predicted yields, where historical rainfall deciles were used to create a range of yield potentials to be trialled.

Yield Target Example

Starting N = 40 kg/ha Average GSR rainfall = 300 mm

Stored moisture = 60 mm
Evaporation = 80 mm

Mineralisation = 50 kg/ha N
WUE = 20 kg/mm/ha

Yield = mm water evaporation*WUE (kg/mm/ha)

In this instance:

Yield = (stored moisture (60) + GSR rainfall (300)) - (evaporation (80))*WUE (20)

Yield = (360-80)*20

Yield = 5.6 t/ha

If the grower requires 40 kg available N in the soil per tonne of grain to be produced the N required is 5.6*40 = 224 kg/ha.

The quantity of N mineralised in the soil, through the breakdown of organic matter, can play a large role in-season supply of N. There are several rules of thumb to determine how much N may be mineralised. In this case we allowed for mineralisation of 50 kg/ha and starting soil N of 40 kg/ha.

This leaves an additional N required = 224 – (50+40) = 134 kg/ha.

When calculated this way, we will need an extra 134 kg N/ha added to the system to achieve the yield potential of this crop in an average season.

What happened?

Cockaleechie

Starting soil mineral N levels in the good site were almost double those in the poor site at Cockaleechie, with the poor site virtually exhausting all mineral N by the end of the season (Figure 1).

Figure 2 demonstrates the increase in net margin (calculated in Tables 1 and 2) on a responsive soil type in a water unlimited year at Cockaleechie. The poor site shows a small initial response to lower rates of N and profit, after which profit plateaus and gradually declines. The good site was highly responsive and profitable with added N.

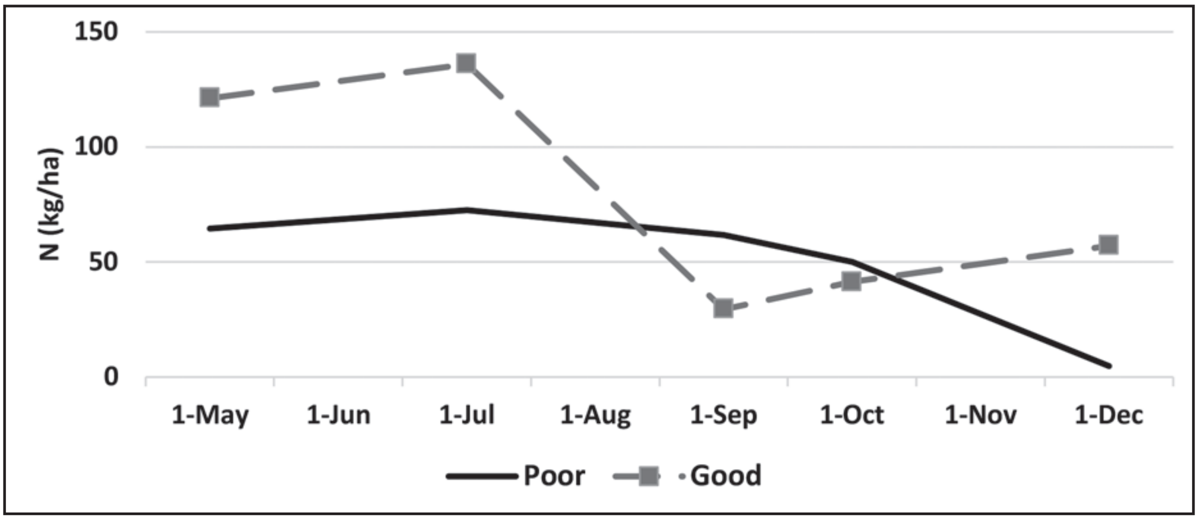

Figure 1. Soil mineral N levels (0-60 cm) at Cockaleechie over the 2022 growing season with no additional N after 14 kg/ha applied at seeding.

Table 1. Cockaleechie poor site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Late N	109	6.09	289	4.85	10.1	1414
50	23	6.73	356	4.04	9.5	1379
Decile 1	34	6.55	302	4.36	9.2	1463
100	46	7.38	380	4.66	9.3	1538
Decile 3	69	6.98	387	4.81	9.5	1515
200	92	8.29	365	4.97	9.5	1509
Decile 5	109	7.02	377	4.93	9.5	1437
Decile 7	163	8.81	433	5.23	9.7	1383
LSD (P=0.05)		*1.2*	*98*	*0.32*	*0.2*	

Table 2. Cockaleechie good site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Control	0	15.9	349	3.3	9.6	1199
Conservative	14	15.5	344	3.4	10.3	1210
Optimum profit	39	18.9	395	4.3	10.4	1538
Optimum yield	63	17.8	364	4.0	10.8	1596
Decile 1	70	17.0	361	4.6	10.6	1812
Decile 2-3	110	18.5	404	4.5	11.4	1786
District practice	136	18.2	380	5.1	11.4	2026
Decile 5	159	18.8	353	4.9	11.9	2076
YP BOM	215	17.6	382	5.2	11.8	2195
Decile 7-8	215	17.6	365	5.2	11.8	2190
LSD (P=0.05)				*0.78*	*0.6*	

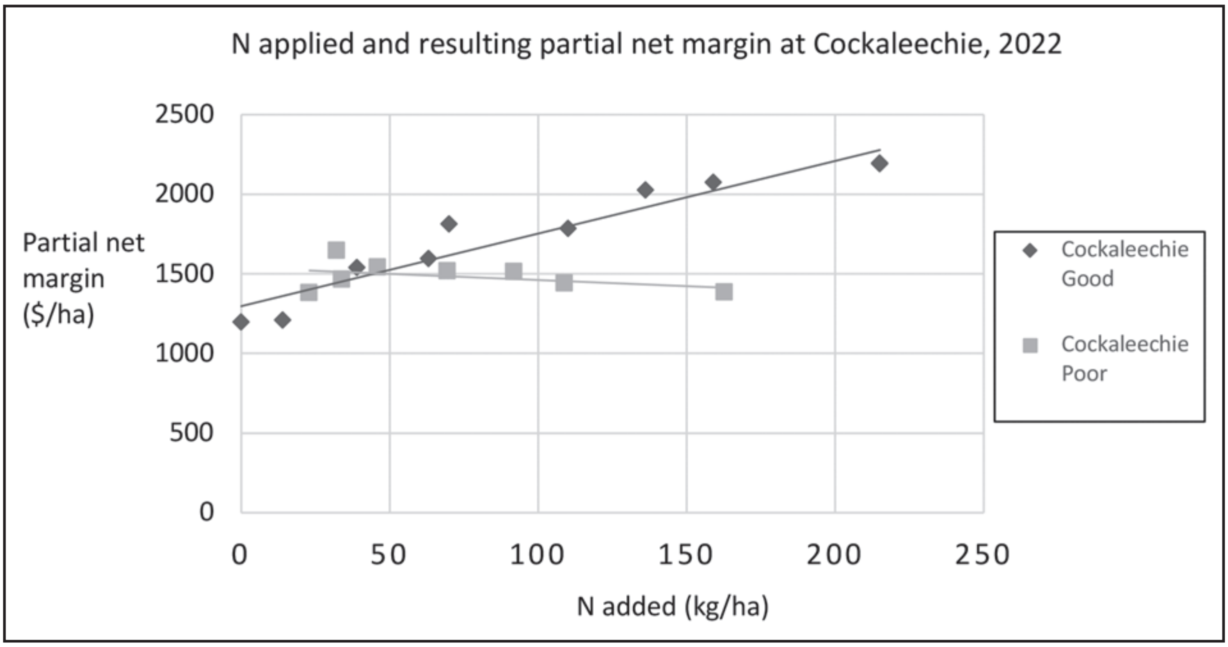

Figure 2. N applied and resulting partial net margin on good and poor areas at Cockaleechie in 2022. Net margins calculated as per Table 1 and Table 2.

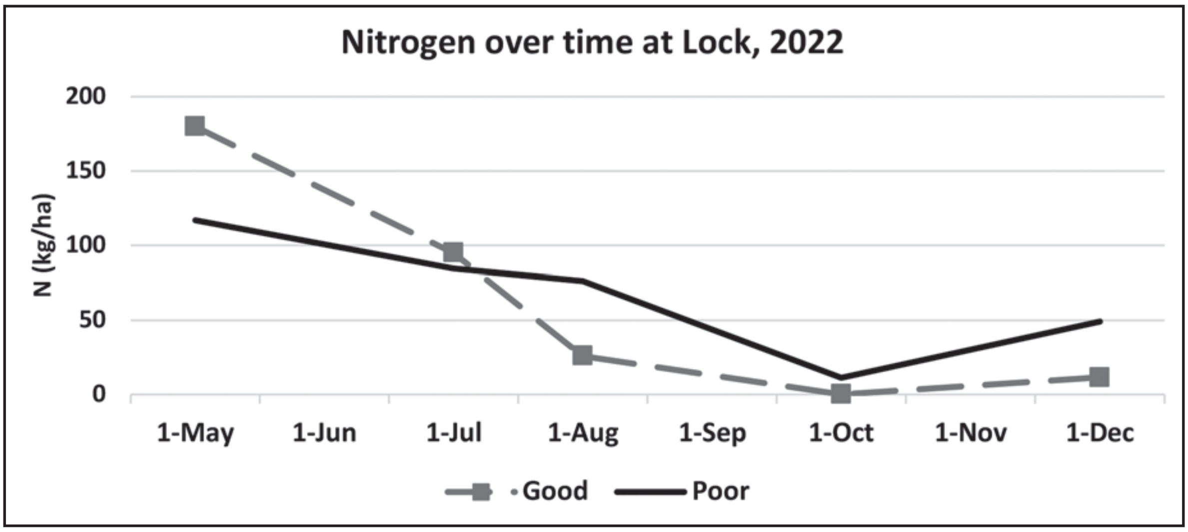

Figure 3. Soil mineral N levels (0-60 cm) at Lock over the 2022 growing season with no additional N after 14 kg/ha applied at seeding.

Lock

There were high starting N levels across both sites at Lock in 2022 (Figure 3). High N use by the crop shown by the large draw down on N during the growing season. While both sites are driven low throughout the growing season, mineralisation is demonstrated with an increase in soil mineral N immediately post crop maturation.

The Lock poor trial displayed an improvement in yield to the addition of N, however the 'good' trial did not (Tables 3 and 4). The primary reason for this is high starting N levels (Figure 3). The Lock good site yielded approximately 6.5 t/ha and the required N to achieve this at 40 kg/t is 260 kg/ha. Taking starting N of 180 kg/ha and 14 kg/ha added at seeding, plus modelled mineralisation of only 44 kg/ha leaves a deficit of 22 kg/ha. This should leave space for yield response and/or protein when additional N is applied. At 6.5 t/ha of yield, other yield constraints come into question such as crop density, other nutrition limitations and water stress. Further research would be required to confirm this.

The trial at Lock demonstrated the importance of understanding starting N levels. However, given the circumstances in 2022, that being high prices and a significant price jump between protein grades, it also demonstrated the value in acquiring marginally more yield or protein. This may not be the case in all seasons.

Table 3. Lock poor site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Late N	32	7.0	271	4.06	9.8	1361
Decile 1	0	7.5	275	3.82	9.6	1365
Decile 3	5	6.9	281	4.13	9.4	1463
50	23	7.6	323	4.05	9.7	1383
Decile 5	32	8.6	300	4.33	9.6	1458
100	46	7.4	309	4.20	9.3	1372
Decile 7	64	8.2	312	4.69	9.5	1488
200	92	10.1	351	4.74	10.1	1426
LSD (P=0.05)		*0.87*	*ns*	*0.17*	*ns*	

Table 4. Lock good site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Late N	26	17.0	360	6.45	10.3	2239
Decile 1	0	16.9	366	6.43	10.0	2305
Decile 3	5	16.6	375	6.54	10.0	2331
50	23	17.6	397	6.47	10.2	2254
Decile 5	26	16.9	420	6.44	10.0	2236
100	46	17.4	396	6.56	10.0	2222
Decile 7	77	17.2	425	6.63	10.4	2148
200	92	17.7	400	6.74	10.5	2416
LSD (P=0.05)		*ns*	*ns*	*ns*	*ns*	

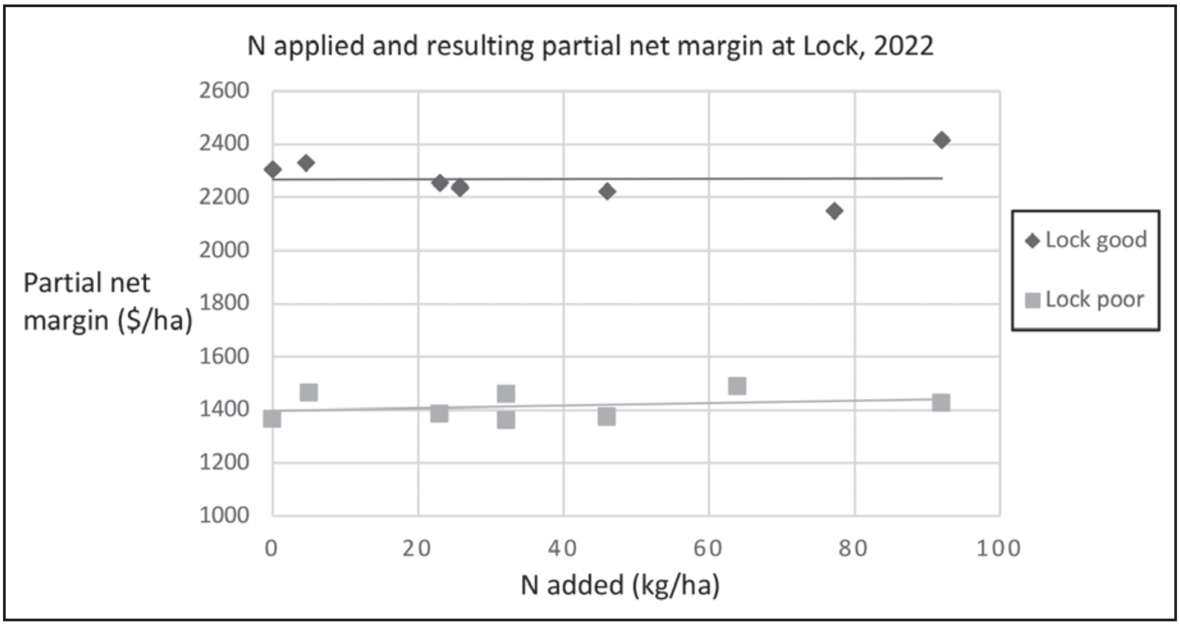

Figure 4. Nitrogen applied to good and poor sites and resulting partial net margins at Lock in 2022.

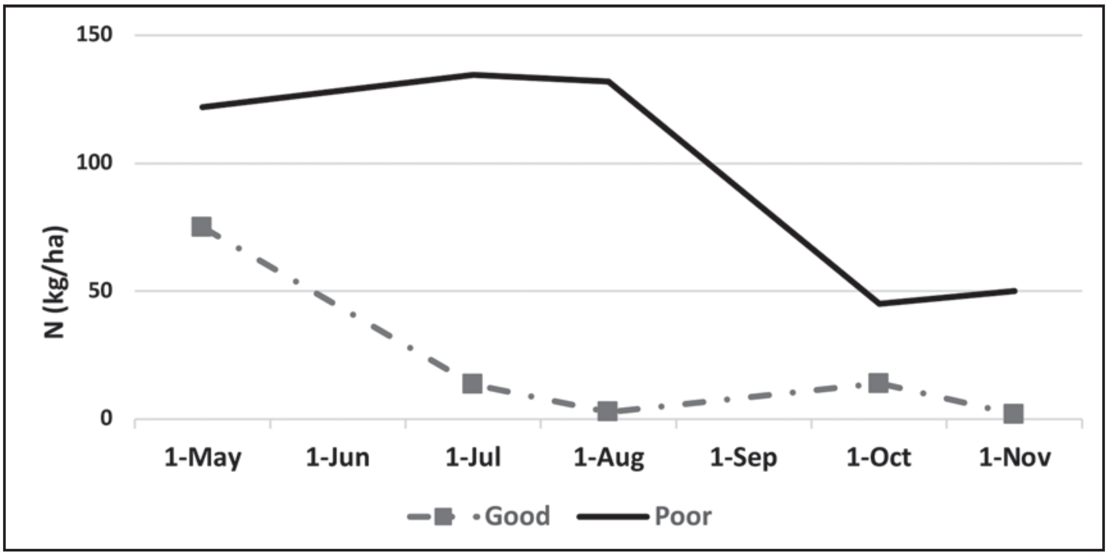

Figure 5. Soil mineral N levels (0-60 cm) at Minnipa over the 2022 growing season with no additional N after 14 kg/ha applied at seeding.

Soils

Table 5. Minnipa poor site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Late N	32	10.0	233	4.17	11.5	1692
Decile 1	0	10.7	169	4.26	11.2	1694
Decile 3	5	9.7	228	4.27	11.2	1684
50	23	12.1	242	4.26	11.1	1629
Decile 5	32	10.0	234	4.34	11.4	1635
100	46	10.1	229	4.35	11.2	1600
Decile 7	64	10.3	239	4.43	11.3	1571
200	92	9.5	234	4.41	11.4	1484
LSD (P=0.05)		*ns*	*ns*	*ns*	*ns*	

Table 6. Minnipa good site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Late N	76	12.5	273	4.37	11.9	1643
Decile 1	0	9.2	214	3.77	10.3	1347
50	23	11.2	229	4.25	10.0	1455
100	46	11.9	246	4.71	10.1	1556
Decile 3	49	12.7	298	4.67	10.2	1522
Decile 5	76	13.2	299	4.97	10.5	1553
200	92	12.0	296	4.70	10.7	1600
Decile 7	108	13.1	302	5.05	10.5	1685
LSD (P=0.05)		*1.12*	*68*	*0.43*	*0.4*	

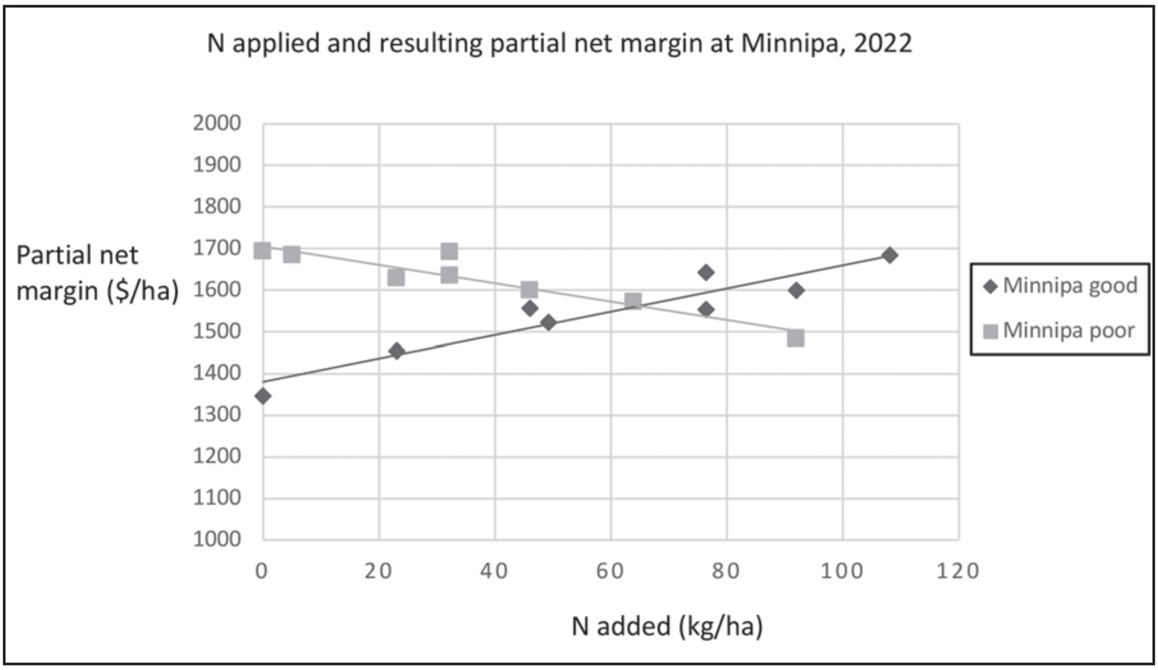

Figure 6. Nitrogen applied to good and poor sites and resulting partial net margins at Minnipa in 2022.

Minnipa

The Minnipa site responded in a similar fashion to Cockaleechie. The good site displayed an increase in partial net margin driven by significant yield and protein responses (Tables 5 and 6). The high starting N at the Minnipa poor site saw no significant response to yield and protein (Figure 5). In turn the money spent on inputs detracted from the partial net margin and resulted in a decline in partial net margins as inputs increased at the poor site (Figure 6).

What does this mean?

Pre-seeding soil testing and historical yield performance helped inform the estimated response to N application in 2022, rather than N application being a guaranteed return, across the board, in a season with high levels of stored soil moisture and above average growing season rainfall. By understanding how much N and plant available water was present in different production zones, forecast yields and N budgets were able to be generated and N responses better predicted.

References

Hunt, J., Kirkegaard, J., Maddern, K., Murray, J (2021), Strategies for long term management of N across farming systems, La Trobe University, National Landcare Program.

Hochman & Horan (2018), Causes of wheat yield gaps and opportunities to advance the water-limited yield frontier in Australia, Field Crops Research 228 (20-30).

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