Two years of testing the nitrogen bank approach at Bute on a sandy soil

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Key findings

- The grain yield of all N management strategies (total N target ranging from 118 – 221 kg N/ha) ranged from 4.91 t/ha to 5.35 t/ha, a difference of 0.44 t/ha, compared to untreated of 3.69 t/ha.
- Higher grain yield in 2023 was related to low grain yield in 2022, and vice versa. Differences in residual moisture are implicated, where lower yielding treatments in 2022 left more unused moisture for use in the 2023 crop compared with the higher yielding treatments in 2022.
- Nitrogen management strategies with total N targets of > 160 kg N/ha were required to build soil N levels (positive N balance) this season.
- Two years of results shows several N strategies were equally profitable (Figure 3), where seven of ten N management strategies tested produced average partial gross margins (PGM) that were within $54/ha of each other over the two seasons.

Why do the trial?

Nitrogen (N) management remains an issue for growers and research has shown N deficiency is considered the biggest single cause of yield gap in Australian wheat. Recently Hunt et al. (2021) developed the concept of N Banks, where enough N is supplied each year to maintain N at a level sufficient to achieve water-limited yield potential in most seasons. In the paddock, this means setting an appropriate N Bank target dictated by annual rainfall and potential yield for each crop location. This approach will require growers to focus more on a longer-term strategy rather than relying on a short-term season by season approach.

'Nitrogen banks' are a strategy for managing N in crop production areas with low environmental losses (leaching, denitrification). Most of the Yorke Peninsula and Mid-North has soils which are free-draining and hold a reasonable amount of water, and therefore, environmental losses of N are low. Exceptions to this are soil types that are prone to waterlogging or very sandy soils which are present in these areas. The advantages of the N Bank approach are that they are simple to calculate, crops are rarely N deficient, and if set at the correct level for the environment, soil organic N is not mined. They also shift the cost of N fertiliser into years following a year of high production, rather than in the year of possible high production.

Nitrogen banks require growers to set a locally relevant target for crop N supply (soil mineral N plus fertiliser N) that is enough to maximise yield in the majority of seasons. Soil mineral N is then measured early in the growing season, and if less than the target N Bank, is topped up to the target value with fertiliser N.

This trial is part of a larger series of experiments in the southern region aiming to compare the productivity (yield, protein), profitability (gross margin, risk) and sustainability (soil organic matter, carbon footprint, N losses) of different management systems over the long term.

How was it done?

Site selection and rainfall

The trial was established 6 km east of Bute, SA in 2022 to evaluate the performance of different N management strategies. Initial soil test results (0-100 cm) from year one are summarised in Table 1. The Bute soil profile is a sand over a sandy loam. The soil pH was slightly acidic in the 0-10 cm moving to neutral and slightly alkaline at depth (Table 1). Soil available phosphorus in the topsoil was high. The site had moderate organic carbon for a sandy soil (0.7%) and low sodicity and salinity.

Soil mineral N pre-seeding in 2022 was 80 kg/ha for the 0-70 cm or 113 kg/ha for 0-100 cm following the previous lentil crop in 2021. In 2023 all plots were sampled for soil mineral N pre-seeding on May 3 (Table 2) to establish any differences among the various N management strategies trialed in season one.

Table 1. Starting soil properties for N Bank trial at Bute, SA sampled in May 2022.

Depth		**0-10 cm**	**10-40 cm**	**40-70 cm**	**70-100 cm**
pH ($CaCl_2$)		6.1	7.9	8.1	8.0
DGT P	µg/L	117			
Organic Carbon	%	0.7			
Conductivity	dS/m	0.09	0.10	0.10	0.11
CEC	cmol/kg	4	17	23	24
ESP	%	0.6	0.3	0.3	0.4

In 2023 Bute received below average growing season rainfall at 225 mm compared to the long-term average rainfall 290 mm (Figure 1). This is a Decile 3 (lowest 30% of rainfall records) for Bute growing season rainfall. The site annual rainfall was 362 mm compared to 391 mm long-term average.

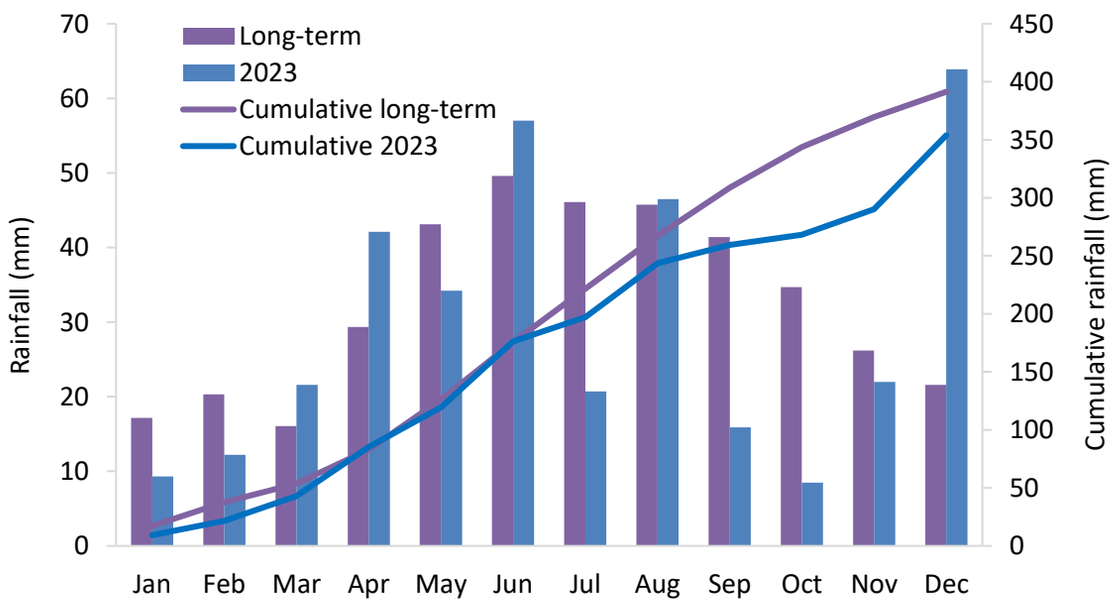

Figure 1. Long-term average and 2023 monthly and cumulative rainfall for N Bank trial at Bute, SA (source: Bute BOM weather station).

Trial design and treatments

The trial was sown to Commodus CL barley at 75 kg/ha on May 16, 2023 following wheat (2022) and lentil (2021). At seeding 130 kg/ha of single superphosphate was applied (no N applied at seeding). The trial was a randomised complete block design and N treatments were applied based on starting soil mineral N results and different N management strategies (Table 2). Three different N management approaches were tested:

- Matching N fertiliser to seasonal yield potential (Yield Prophet® and Yield Prophet Lite, YP)
- Maintaining a base level of fertility using N fertiliser (N Banks)
- District practice

All treatments were compared to a nil N control. Within the Yield Prophet and N Bank systems, there were additional treatments targeting different yield potentials (Table 2). 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 32 kg N /ha per tonne barley yield. For the N Bank treatments, there were different target levels of N fertility (N Banks). Nitrogen fertiliser rates in these treatments were calculated from the N Bank value (average crop yield potential at Bute 4.0 t/ha = 160 kg N/ha) minus soil profile mineral N measured prior to sowing. All N was applied as urea in a single top-dress application on July 7, 2023 prior to 5 mm of rainfall.

Table 2. Nitrogen management strategies and pre-seeding soil mineral N (May 3, 2023) in the N Bank trial Bute, SA in 2022 and 2023.

Treatment	Nitrogen applied to wheat 2022	Soil mineral nitrogen 2023	Nitrogen applied to barley 2023	Total N target (soil + fert) 2023	Description
	kg N/ha				
Control	0	44	0	44	No N applied
District Practice	121	59	85	144	Generally based on 32 kg N/tonne barley & average yield target of 4.8 t/ha. However, the rate here was capped at 85 kg N/ha as rates above this in the district are rare.
N Bank Conservative	22	54	81	135	Optimal profit minus 25 kg N/ha
N Bank Optimum Profit	47	51	109	160	Based on the relationship between optimal N Bank and rainfall. This season Decile 5 grain yield of 5 t/ha requires 160 kg N/ha minus starting soil available N
N Bank Optimum Yield	72	54	131	185	Optimal profit plus 25 kg N/ha
*YP BOM	143	65	54	118	Based on BOM season outlook. At the time was predicting a high chance (40%) of below average spring rainfall (decile 1&2). Target potential yield 3.7 t/ha.
YP Decile 1	0	46	72	118	Yield with lowest yielding season finish on record (Decile 1, severe drought). Target potential yield 3.7 t/ha.
YP Decile 2-3	15	73	71	144	Yield with lower yielding quartile season finish (Decile 2-3, moderate drought). Target potential yield 4.5 t/ha.
YP Decile 5	55	46	133	179	Yield with median season finish (Decile 5, 50%, average season). Target potential yield 5.6 t/ha.
YP Decile 7-8	99	52	169	221	Yield with higher yielding quartile season finish (Decile 7-8, favourable season). Target potential yield 6.9 t/ha.

**Yield Prophet Lite was used for yield predictions*

Crop assessments

Crop assessments included GreenSeeker NDVI measured on July 24 and September 1, 2023. Harvest index (HI) cuts were completed at maturity by removing 4 x 0.5 m row at ground level in each plot. Samples were oven dried at 70°C for 48 hours, weighed, threshed and separated into grain and stem /leaf and HI calculated. Grain yield plots were harvested with a plot header on October 27, 2023 and grain yield (t/ha) determined. Grain quality assessment included protein (%) and grain N removal was calculated as the product of grain N content and grain yield multiplied by a protein conversion factor 1.75. Fertiliser recovery N use efficiency (NUE) is the amount of applied fertiliser N recovered in the harvested grain for both trial years. It was calculated as treatment grain N removal minus control grain N removal divided by fertiliser applied (kg N/ha) to the specific treatment. Partial N balance was calculated as fertiliser N minus grain removal.

Results and discussion

Soil mineral nitrogen

The 2023 season pre-seeding soil mineral N levels ranged from 44 kg N/ha to 73 kg N/ha from N rates (ranging from 0 – 143 kg N/ha) applied in 2022. This was a difference in starting soil N of 29 kg N/ha from all N management strategies. There was a poor correlation between last year's fertiliser N rate and soil mineral N which is not commonly expected. This can be explained by above average 2022 spring rainfall resulting in high crop N uptake and negative N balances.

Crop biomass and HI

Crop biomass (measured as NDVI) in late July showed all N treatments had similar NDVI readings averaging 0.69 compared to 0.60 for the untreated control (data not shown). Five weeks later, in early September, NDVI measurements indicated there were only minor differences among the N treatments (Table 3).

Harvest index (HI) is the ratio of grain to total shoot dry matter and is a measure of the crop's reproductive efficiency. In average seasons, the HI is typically 0.3-0.4, compared to drier seasons when the harvest index can be closer to 0.5. Results from the current below average season are in line with this as the majority of N strategies had HI close to 0.5 (Table 3). Over supply of N early in the season can also lead to lower HI because of excessive biomass. This was also observed at Bute with low HI values of 0.41 and 0.44 resulting from the highest total N targets of 221 kg N/ha and 185 kg N/ha.

Grain yield and protein

The grain yield of the different N management strategies (total N target ranging from 118 – 221 kg N/ha) ranged from 4.91 t/ha to 5.35 t/ha, a difference of 0.44 t/ha. Given this small difference it is not surprising there was little variation in grain yield response among the N strategies trialed this season. A number of treatments were high yielding including NB conservative, NB Optimum Profit, YP Decile 1, YP Decile 3, YP Decile 5, NB Optimum Yield and District Practice (Table 3). Interestingly, these tended to be lower yielding treatments the season prior (2022).

Comparison of both seasons of grain yield data shows treatments in 2022 impacted barley yields in 2023. Nitrogen management strategies which had higher grain yields in 2022 were generally followed by lower yields in 2023 (Figure 2). Given NDVI data did not show any clear correlation with starting soil N (i.e. more carry over N from previous high N rates), it suggests this reduction in yield maybe related to soil water. Nitrogen strategies which applied higher fertiliser rates in 2022, stayed greener for longer due the wet spring and potentially used more water. It is this difference in residual water that has had a significant impact on yield this season.

Table 3. GreenSeeker NDVI, harvest index, grain yield (t/ha), protein (%), grain N removal, partial N balance, average fertiliser recovery NUE (2022 & 2023) and partial gross margin ($/ha) from N Bank trial at Bute, SA 2023.

Treatment	Soil mineral N + fertiliser N (kg N/ha)	= Total N (kg N/ha)	NDVI Sept 1	Harvest Index	Grain yield (t/ha)	Protein (%)	Nitrogen removal (kg N/ha)	Average fertiliser recovery (NUE)	Partial N balance (kg N/ha)	Partial gross margin* $/ha
Control	44 + 0	44	0.58 c	0.51 a	3.69 e	7.0 f	45 g		-45	1,292
District Practice	59 + 85	144	0.71 b	0.45 c	5.04 bcd	10.6 cd	94 cde	41%	-9	1,670
N Bank Conservative	54 + 81	135	0.72 ab	0.51 a	5.35 a	9.1 e	86 ef	53%	-4	1,785
N Bank Optimum Profit	51 + 109	160	0.75 ab	0.47 bc	5.16 abc	10.6 cd	96 bcd	49%	12	1,689
N Bank Optimum Yield	54 + 131	185	0.77 a	0.44 cd	5.08 bcd	11.9 b	106 ab	45%	25	1,635
YP BOM	65 + 54	118	0.75 ab	0.46 bc	4.94 cd	10.1 d	88 def	44%	-34	1,671
YP Decile 1	46 + 72	118	0.75 ab	0.50 ab	5.27 ab	8.6 e	80 f	48%	-8	1,765
YP Decile 3	73 + 71	144	0.76 ab	0.52 a	5.28 ab	8.6 e	80 f	51%	-9	1,770
YP Decile 5	46 + 133	179	0.75 ab	0.47 bc	5.25 ab	11.2 bc	104 abc	43%	29	1,693
YP Decile 8	52 + 169	221	0.77 a	0.41 d	4.91 d	12.8 a	111 a	39%	58	1,534
		Pr(>F)	<0.001	<0.001	<0.001	<0.001	<0.001			
		LSD (P≤0.05)	0.06	0.04	0.16	0.9	10			

*Partial gross margin was calculated as grain yield x grain price – urea applied (kg /ha) /1000*urea price. Assumed 2023 pricing BAR1 = $350/tonne and urea = $500/tonne.*

Even where no additional N was applied, barley yields were 3.69 t/ha (Table 3). Soil mineral N was low in the control (44 kg N/ha) following high wheat yields in 2022 (Trengove et al. 2022). The N removal results show 45 kg N/ha was removed in the grain. Depleting this supply of N in the long-term is not sustainable.

Fertiliser NUE values reported here are in line with industry values of 30 – 50%. The values presented in Table 3 are the average of both years' fertiliser applications and N removal. They show in general 39 – 51% of the N fertiliser applied was recovered in the grain in the two years of the trial. The fate of the other 49-61% includes the crop residues, soil mineral N and losses to the environment.

Grain protein for all treatments ranged from 7.0 – 12.8% (Table 3). Currently Commodus CL has a maximum delivery grade of feed (no protein limit) however, it is undergoing malt accreditation. Treatments falling outside the protein levels for malt receival standard (9.0 - 12.0%) were the Control, YP Decile 1, YP Decile 3. N Bank Conservative was border line at 9.1%. The highest N strategy this season (YP Decile 8 = 221 kg N/ha) was the only treatment to exceed 12.0%.

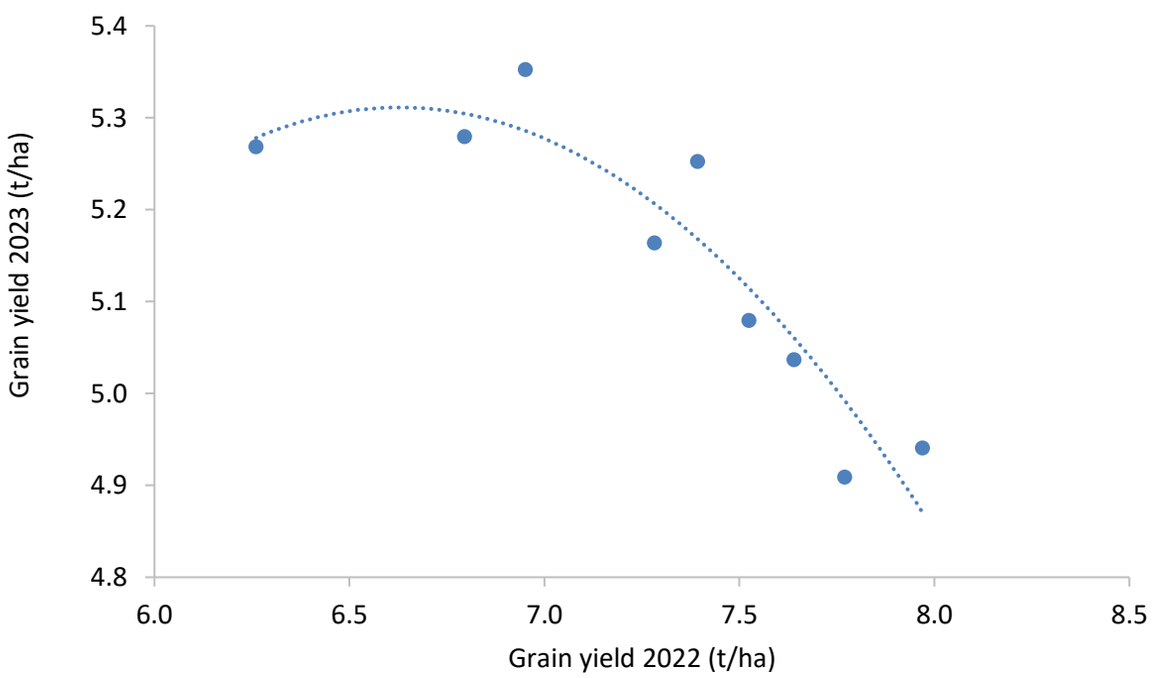

Figure 2. Relationship between wheat grain yield (2022) and barley grain yield (2023) from the various N management strategies, excluding the nil.

Patrial gross margin and N balances

Comparison of the different systems shows that N Bank Conservative (135 kg N/ha total N) was the most profitable treatment this season (Table 3). This was followed by two other conservative N management strategies achieving similar levels of profit (within $20/ha); YP Decile 3 and YP Decile 1.

The partial N balance from all treatments ranged from negative (mining soil N) 45 kg N/ha to positive (increasing soil mineral N) 58 kg N/ha (Table 3). This season N management strategies with total N targets of 160 to 221 kg N/ha resulted in positive N balances of 12 to 58 kg N/ha. Management strategies with total N targets of 144 kg N/ha or less mined N from the system.

Reviewing two years of results shows several N strategies were equally profitable (Figure 3), where seven of ten N management strategies produced average partial gross margins (PGM) that were within $54/ha of each other. The treatments that fall outside of this group were the annual low input strategies (Nil, YP Decile 1) and annual high input strategy (YP Decile 8). Given the seasons rainfall were Decile 7 in 2022 and Decile 3 in 2023, it is not surprising these treatments have not performed well in both years. In contrast, treatments that respond to the season, or target moderate inputs performed better. This outcome is supported by a previous long-term trial carried out by Hunt et al. (2021) at Curyo, Victoria.

The data from Bute also shows profit is maximised at slightly negative (-30 kg N/ha) partial N balance and gross margin begins to decline at an N balance ±20 kg N/ha from this value. In general, the lower N input strategies that optimise PGM are lower risk and provide a higher return on investment in the short term. Conversely, the higher input strategies that optimise PGM may result in a lower return on investment in the short term (due to a higher cost base) but, longer term will be more sustainable agronomically with neutral to positive N balances (more N applied in fertiliser than removed in grain) indicating soil organic N is not being mined.

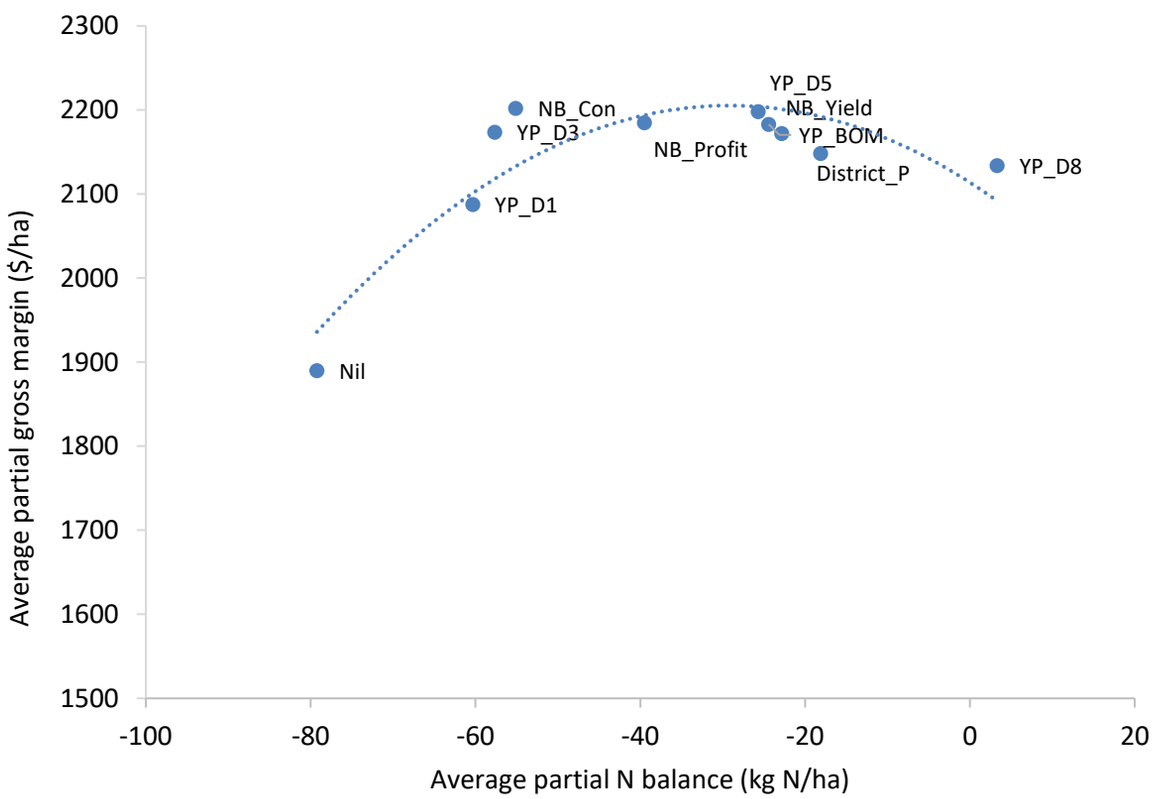

Figure 3. The relationship between average (2022 and 2023) partial N balance and average partial gross margin for the different N treatments trialed at Bute, SA.

Conclusions

This project aims to demonstrate to growers how to reduce the yield gap from N deficiency, increase profit, and stop mining soil organic matter by taking a longer-term view of N management. Below average growing season rainfall resulted in barley grain yields at Bute ranging from 3.69 t/ha to 5.35 t/ha. A number of N management strategies were high yielding including NB Conservative, NB Optimum Profit, YP Decile 1, YP Decile 3 and YP Decile 5, but this was largely linked to production in 2022 where lower yielding treatments in that year performed comparatively better in 2023 and vice versa. Soil water dynamics are important in this interaction.

Reviewing two years of results shows several N strategies were equally profitable. Currently the data shows profit is maximised at a slightly negative (-30 kg N/ha) partial N balance. However, over the longer term, while it is expected these strategies will remain the most profitable, they are likely to have neutral to positive N balances (more N applied in fertiliser than removed in grain) indicating soil organic N is not being mined.

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