

# Nitrogen banking approach for clay-loam soil in the medium rainfall zone of SA

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## Key findings

- Two contrasting seasons were observed at the N Bank trial site from 2022 – 2023 at Kybunga, SA receiving 552 mm and 407 mm of annual rainfall, respectively.
- In 2022, all nitrogen (N) management treatments resulted in a negative partial N balance (kg N/ha), indicating soil N was mined. This occurred to a smaller extent in 2023, with several treatments in positive N balance (partial N balance ranging from -62.1 to +30.7 kg N/ha).
- Barley yield response to N treatments was moderate (0.77 t/ha difference) with yields ranging from 4.36 – 5.13 t/ha. Several treatments yielded well in 2023 including N Bank Conservative, N Bank Optimum Profit, YP Decile 5 and YP Decile 7 (applied N ranging from 34 – 93 kg N/ha).
- The N Bank conservative treatment (160 kg/ha total N) was the most profitable treatment at Kybunga in 2023 with a partial gross margin of \$1,655.
- Although not the most profitable, cumulative partial N balance (2022 and 2023) shows that YP Decile 8 and N Bank Optimal Yield treatments have reduced mining of soil mineral N, across two good production years at Kybunga, SA.

## Background

Nitrogen (N) deficiency is the most significant factor contributing to grain yield gaps within Australian cropping systems, reducing in on-farm profitability (Hunt, 2020). It is suggested that national wheat yields could increase by up to 40% by alleviating N deficiency (Hochman and Horan 2018).

Two strategies can be implemented to manage N application, including traditional nitrogen budgeting which attempts to match N to seasonal yield potential, or strategic nitrogen sequence targets, otherwise known as the nitrogen banking approach (N Banks). Generally, our tactical approach to in-crop N management targets a particular yield or seasonal outcome, using the 40 kg/N per tonne of wheat rule. If we know how much N is available to the crop as soil mineral N, we know how much extra to add. But we also know that if we are unlikely to hit this target, we are going to either under-fertilise and regret being too cautious or over-fertilise and regret being too optimistic (Allen et al., 2023). The national average for in-crop nitrogen application is currently 45 kg N/ha which is one of the main reasons for the gap between actual and potential yields (Hunt et al., 2022).

Nitrogen banking is a strategy to simplify a management decision and manage N in crop production across areas with low environmental losses, such as leaching and denitrification. The nitrogen banking approach ensures adequate N is applied to maintain levels that can achieve water-limited potential yield (PYw) potential in most seasons (Tregrove, 2022). This is a long-term and strategic approach, where an appropriate N Bank target is implemented for crop N supply. This is determined by yield potential and environment at a specific location.

Some of the biggest advantages associated with N banking is that soil organic N is not mined if targets are set correctly. This is important as unused fertiliser maintains the fertility of continuous cropping systems, with crops like wheat only sourcing 30-40% of their nitrogen requirement from fertiliser (Hunt, 2023). This N strategy also moves the cost of nitrogen fertiliser from seasons with a high production potential, into seasons following a high production year (Trenrove, 2022).

## Methodology

### Site selection and rainfall

A trial was established at Kybunga in 2022 as a series of long-term experiments across the southern region, aiming to evaluate the productivity (yield and protein), profitability (gross margin) and sustainability (soil organic matter, carbon and N losses) of long-term N management systems. The Kybunga site is located within the medium rainfall zone of the Mid-North region on a light clay-loam soil type. Soil mineral N levels were high in 2022 (Table 1), following the previous year's field pea crop with a total of 147 kg N/ha (0 – 100 cm). Topsoil pH was neutral (pH 7) at 0 – 10 cm, increasing to alkaline at depth (10 – 100 cm). Phosphorous availability by DGT P was adequate (60.1 µg/L) and salinity slightly high (> 15 dS/m).

Table 1. Soil properties for the Kybunga, SA trial site sampled May 4, 2022.

Soil properties	Units	Depth (cm)			
		0-10	10-40	40-70	70-100
Available N (nitrate + ammonium)	Kg/ha	50.5	50.4	27.2	18.9
pH (CaCl <sub>2</sub> )		7	8	8	8
DGT P	µg/L	60.1			
Organic carbon	%	1.3			
Conductivity (salt)	dS/m	0.17	0.19	0.16	0.22
CEC (Cation exchange capacity)	cmol/kg	21.8	33.4	28.2	28.3
ESP (Exchangeable sodium percentage)	%	0.8	0.6	1.1	4.2

The site received above average annual rainfall of 552 mm in 2022, compared to the long-term average of 428 mm (Figure 1). Growing season rainfall (GSR) received was 384 mm (April – October). In 2023, the Kybunga site received below average rainfall of 407 mm, with 275 mm contributing to GSR.

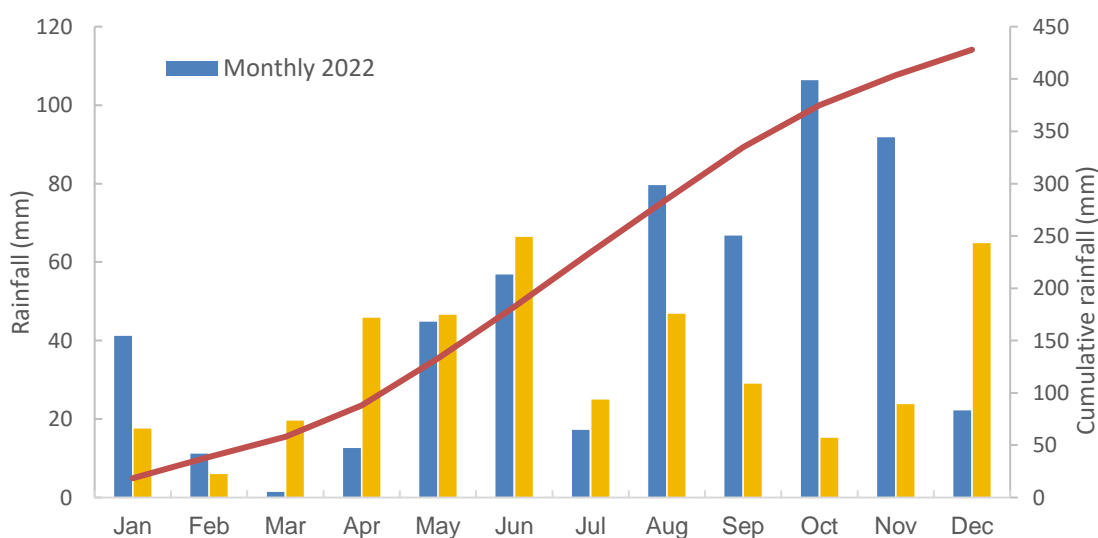


Figure 1. Monthly rainfall at Kybunga trial site for 2022 and 2023 seasons (Source: Kybunga Mesonet). Cumulative long-term average annual rainfall (428 mm) at site is also shown.

### Trial design and treatments

The trial was sown to Compass barley at 150 plants/m<sup>2</sup> (~80 kg/ha) on May 17, 2023, after Scepter wheat in 2022 (Table 2). The trial was a randomised complete block design, evaluating ten N management strategies (Table 3), based on starting soil mineral N results each season. Across the ten treatments, three core N management approaches were tested:

1. Matching N fertiliser to seasonal yield potential (Yield Prophet<sup>®</sup>)
2. Target N fertiliser rate to maintain a base level of fertility (Nitrogen banking)
3. District practice (45 kg N/ha)

Yield Prophet<sup>®</sup> was used to evaluate yield spread as probabilities at Kybunga, based on starting soil water and available N. This determined several treatments across decile outcomes (1 – 8). The amount of N calculated for these treatments was determined by the difference between water limited yield (PY<sub>w</sub>) and nitrogen limited yield potential (PY<sub>N</sub>). The amount of N required to achieve these yields assumed a requirement of 40 kg N /ha per tonne of barley.

An 'optimal profit' N Bank target was selected based on the relationship between average annual rainfall and the minimum N Bank target required to achieve average economic yield. Optimal Yield and Conservative targets were plus and minus 25 kg N/ha from the optimal profit treatment respectively. Nitrogen fertiliser rates in these treatments were calculated from the N Bank value, minus soil profile mineral N measured prior to sowing. All N was applied as urea in a single top-dress application in July, plus 6 kg N/ha was applied through MAP fertiliser at seeding.

Crop measurements included plant counts (plants/m<sup>2</sup>) and harvest index (HI) which were conducted at maturity by removing 4 rows x 0.5 m at ground level in each plot. Samples were oven dried at 70°C for 48 hours, weighed, and then threshed to separate grain from stem and leaf, to calculate harvest index (HI). Harvest index is defined by the ratio of grain to total shoot dry matter (leaf and stem) and is a measure of reproductive efficiency.

The trials were harvested to determine grain yield (t/ha) and quality measurements were completed to measure protein (%), screenings (%), test weight (kg/hL) and retention (%) (barley only). Grain N removal was also calculated as a product of grain N content and yield multiplied by a protein conversion factor of 1.75.

All 2022 and 2023 trial data was analysed using a REML spatial model (Regular Grid) in Genstat 23<sup>rd</sup> edition.

Table 2. Site details for 2022 and 2023 nitrogen banking trial at Kybunga, SA.

<b>2022</b>	<b>Plot size</b>	2.0 m x 10.0 m	<b>Fertiliser</b>	Seeding: MAP (10:22) + 1% Zn @ 60 kg/ha
	<b>Seeding date</b>	May 28, 2022		
	<b>Crop</b>	Scepter wheat		
	<b>Seed rate</b>	180 plants/m <sup>2</sup>	<b>N application</b>	July 15, 2022
	<b>Harvest date</b>	December 23, 2022		
<b>2023</b>	<b>Plot size</b>	2.0 m x 10.0 m	<b>Fertiliser</b>	Seeding: MAP (10:22) + 1% Zn @ 60 kg/ha
	<b>Seeding date</b>	May 17, 2023		
	<b>Crop</b>	Compass barley		
	<b>Seed rate</b>	150 plants/m <sup>2</sup>	<b>N application</b>	July 26, 2023
	<b>Harvest date</b>	October 27, 2023		

Table 3. Nitrogen treatments evaluated each season in Kybunga N banking trial.

Treatment	Description
<b>Control</b>	No N applied (Nil)
<b>District Practice</b>	Generally based on national average of 45 kg N/ha
<b>N Bank Conservative</b>	Optimal profit minus 25 kg N/ha
<b>N Bank Profit Optimum</b>	Based on the relationship between optimal N Bank and rainfall
<b>N Bank Yield Optimum</b>	Optimal profit plus 25 kg N/ha
<b>*YP BoM</b>	Based on BoM season outlook at time of application (generally a three-month outlook)
<b>YP Decile 1</b>	Yield with lowest yielding season finish on record (Decile 1, severe drought)
<b>YP Decile 2-3</b>	Yield with lower yielding quartile season finish (Decile 2-3, moderate drought)
<b>YP Decile 5</b>	Yield with median season finish (Decile 5, 50%, average season)
<b>YP Decile 7-8</b>	Yield with higher yielding quartile season finish (Decile 7-8, favourable season)

\*YP = Yield Prophet®

## Results and discussion

### 2022 Results

Nitrogen treatments ranged from 0 – 96 kg N/ha at Kybunga in 2022 (Table 4). District Practice (45 kg N/ha), Decile 1 and Decile 2 – 3 treatments had no in-crop fertiliser applied as sufficient N was available (soil mineral N + seeding N) to produce a 3.8 t/ha wheat crop, based on the 40 kg N per tonne wheat rule. Above average rainfall of 552 mm achieved grain yields ranging from 5.44 – 6.52 t/ha (Table 5), with YP BoM and YP Decile 7 – 8 the highest performing treatments, both targeting above average rainfall seasons (6.2 t/ha PYw). Both treatments met APW1 receival standards (protein <11.5%). All other treatments met ASW1 (protein <10.5%). All treatments had low screenings (3.8%) and high test weight (83.1 kg/hL).

Table 4. Nitrogen treatments and pre-seeding soil mineral N at Kybunga in 2022 and 2023.

Treatment	2022		2023			
	Applied N (kg/ha)	PYw (t/ha)	Soil N + starter fert (kg N /ha)	Partial N supply (soil + all fert) (kg/ha)	PYw (t/ha)	Applied N (kg/ha)
Control	0		86 + 6	92		0
District Practice	0		86 + 6	138		46
N Bank Conservative	8		86 + 6	160		68
N Bank Optimum Profit	33		86 + 6	185		93
N Bank Optimum Yield	58		86 + 6	210		118
YP BoM	96	7.8	86 + 6	236*	7.8*	144*
YP Decile 1	0	2.7	86 + 6	92	2.7	0
YP Decile 3	0	3.9	86 + 6	104	3.9	12
YP Decile 5	40	4.5	86 + 6	126	4.5	34
YP Decile 7	96	5.9	86 + 6	168	5.9	76

\*Nitrogen for YP BoM treatment was incorrectly applied and should have been 104 kg N/ha, based on BoM three-month forecast predicting a 46% chance of Decile 2 – 3.

Table 5. Grain yield (t/ha), partial gross margin and partial N balance (kg N/ha) for all N management strategies at Kybunga in 2022. Partial N balance is calculated as grain N removal – N fertiliser applied.

Treatment	Grain yield (t/ha)	Partial gross margin (\$/ha)	Partial N balance (kg N/ha)
Control	5.50 <sup>ab</sup>	2,036	-92.7
District Practice	5.76 <sup>bcd</sup>	2,131	-98.5
N Bank Conservative	5.66 <sup>abc</sup>	2,074	-86.9
N Bank Optimum Profit	5.87 <sup>cd</sup>	2,084	-68.1
N Bank Optimum Yield	6.02 <sup>d</sup>	2,076	-49.5
YP BoM	6.52 <sup>e</sup>	2,227	-25.5
YP Decile 1	5.44 <sup>a</sup>	2,012	-91.6
YP Decile 3	5.61 <sup>abc</sup>	2,075	-94.5
YP Decile 5	6.03 <sup>d</sup>	2,125	-63.1
YP Decile 7	6.51 <sup>e</sup>	2,223	-23.6

## 2023 results

### *Soil mineral nitrogen*

Following a high production year for wheat in 2022, pre-seeding soil mineral N was similar across all treatments with a site average of 80 kg N/ha at Kybunga in 2023. Nitrogen rates applied to treatments varied, ranging from 0 – 236 kg N/ha (Table 4).

### *Crop HI, grain yield and protein*

Harvest index (HI) as a ratio of grain to total shoot dry matter was similar for all treatments at Kybunga in 2023 with a site average of 0.49 (P=0.075). Harvest index values of 0.5 can be expected in a well-managed barley crop.

Barley yield response to varying N treatments was moderate (0.77 t/ha difference) with yields ranging from 4.36 – 5.13 t/ha (Table 6). Several treatments yielded well in 2023 including N Bank Conservative, N Bank Optimum Profit, YP Decile 5 and YP Decile 7. In control and Decile 1 treatments where no N was applied, barley yields achieved 4.36 – 4.37 t/ha, respectively. Grain N removal results show that 60 – 62 kg N/ha was removed, mining soil N. Barley protein ranged from 7.2 – 12.9% across N management strategies. District practice (45 kg N/ha) and N Bank Conservative (160 kg N/ha) met MALT 2 receival standards (screenings >7% to meet Malt 1) with protein levels ranging from 9.6 – 9.9%.

Similar trends were observed across reduced N management strategies with improved screenings, retention and test weight across the control, and Decile 1 – 5 treatments. Screenings ranged from 14.1 – 22.6% in high N management strategies, however all treatments had similar grain to shoot ratios when harvest index was measured. This may result from higher N treatments producing greater biomass or tiller number in comparison to lower N treatments, however coupled with a drier season, these higher yielding treatments resulted in overall reduced grain weight. Similar observations were noted in previous nitrogen experiments across NSW (Bellata and Narrabri), showing that increasing N application rates significantly increased grain screening levels (Daniel et.al., 2016).

The error in N application in 2023 to the YP BoM treatment (46% chance of Decile 2 – 3) increased applied N to 144 N/ha (> Decile 7). Although lower yielding than best performing treatments, it still achieved 5.01 t/ha. Protein also exceeded 12%, failing to meet malt specifications.

### *Partial gross margin and N balance*

A comparison of various N management systems at Kybunga in 2023, shows that the N Bank Conservative (160 kg N/ha total N) was the most profitable treatment with a partial gross margin of \$1,655. Similar results were also observed at Bute, SA in 2023 (Tregove et.al., 2023). Nitrogen management strategies achieving similar levels of profit (within \$100/ha) were District Practice and YP Decile 5.

The N management strategy with the lowest partial gross margin in 2023 was the control treatment, achieving \$1,372/ha (-\$283 compared to N Bank conservative). A two-year partial gross margin (Figure 3) shows that YP Decile 7 has been the most profitable N treatment overall to date, this is likely a reflection of the favourable season carrying over from 2022, where this treatment capitalised from a high production year with sufficient N to exceed PYw of 6.2 t/ha.

Partial N balances (grain N removal – N fertiliser applied) at Kybunga ranged from -62 to +31 kg N/ha. This shows that all N management strategies mined soil N from the system in 2023. This result shows N management strategies with total N targets of  $\geq 210$  kg N/ha resulted in positive N balances of 12.7 – 30.7 kg N/ha. Cumulative partial N balance (2022 and 2023) displayed in Figure 3 show that YP Decile 7 and N Bank Optimal Yield have reduced mining of soil mineral N.

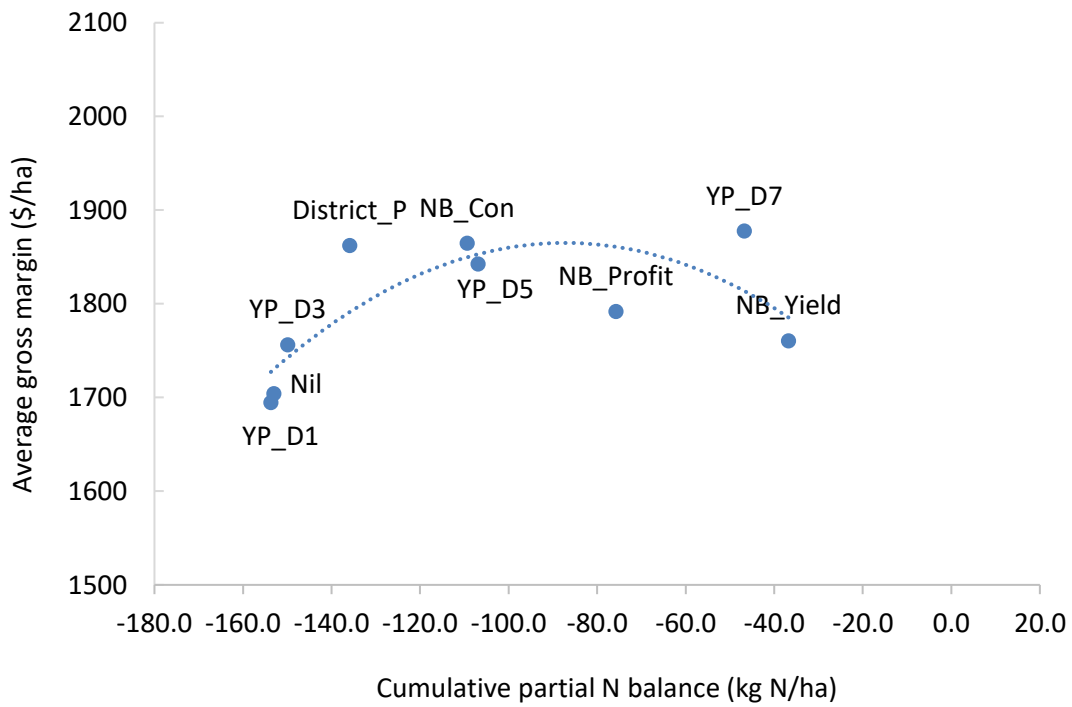


Figure 3. The relationship between average (2022 and 2023) partial N balance and average partial gross margin for N treatments trialed at Kybunga. YP BoM treatment has been excluded from this data set.



Table 6. Grain yield (t/ha), protein (%), screenings (%), test weight (kg/hL), retention (%), grain N removal, partial N balance and partial gross margin (\$/ha) for N bank trial at Kybunga, SA 2023. Shaded values represent the best performing treatments in each column.

Treatment	Applied N fertiliser (kg N/ha)	Grain yield (t/ha)	Protein (%)	Screenings (%)	Retention (%)	Test weight (kg/hL)	Grain N removal (kg N/ha)	Partial N balance (kg N/ha)	Cumulative partial N balance (kg N/ha)	Average partial gross margin* \$/ha
Control	0	4.36 <sup>a</sup>	7.9 <sup>a</sup>	3.8 <sup>a</sup>	96.3 <sup>f</sup>	70.5 <sup>ef</sup>	60.4 <sup>a</sup>	-60.4	-153.1	1,704
District Practice	46	4.98 <sup>c</sup>	9.6 <sup>d</sup>	9.7 <sup>b</sup>	89.1 <sup>d</sup>	69.6 <sup>de</sup>	83.5 <sup>d</sup>	-37.4	-135.9	1,862
N Bank Conservative	68	5.24 <sup>d</sup>	9.9 <sup>d</sup>	10.0 <sup>b</sup>	88.0 <sup>d</sup>	69.1 <sup>cd</sup>	90.6 <sup>e</sup>	-22.5	-109.4	1,865
N Bank Optimum Profit	93	5.08 <sup>cd</sup>	11.3 <sup>e</sup>	17.2 <sup>cd</sup>	81.1 <sup>b</sup>	68.3 <sup>bc</sup>	100.8 <sup>f</sup>	-7.6	-75.7	1,792
N Bank Optimum Yield	118	4.99 <sup>c</sup>	12.1 <sup>f</sup>	18.4 <sup>d</sup>	79.4 <sup>b</sup>	67.8 <sup>ab</sup>	105.3 <sup>g</sup>	12.7	-36.8	1,760
YP BoM	144	5.01 <sup>c</sup>	12.9 <sup>g</sup>	22.6 <sup>e</sup>	75.7 <sup>a</sup>	67.3 <sup>a</sup>	113.1 <sup>h</sup>	30.7		
YP Decile 1	0	4.37 <sup>a</sup>	8.1 <sup>ab</sup>	4.8 <sup>a</sup>	95.2 <sup>ef</sup>	70.7 <sup>f</sup>	62.3 <sup>a</sup>	-62.1	-153.7	1,694
YP Decile 3	12	4.61 <sup>b</sup>	8.4 <sup>bc</sup>	6.2 <sup>a</sup>	93.6 <sup>e</sup>	70.2 <sup>ef</sup>	67.5 <sup>b</sup>	-55.5	-149.9	1,756
YP Decile 5	34	5.07 <sup>cd</sup>	8.8 <sup>c</sup>	5.8 <sup>a</sup>	93.4 <sup>e</sup>	70.6 <sup>ef</sup>	77.7 <sup>c</sup>	-43.8	-106.9	1,842
YP Decile 7	76	5.13 <sup>cd</sup>	11.1 <sup>e</sup>	14.1 <sup>c</sup>	83.6 <sup>c</sup>	68.2 <sup>ab</sup>	99.0 <sup>f</sup>	-23.1	-46.7	1,878
<b>Malt 1 receiving standards</b>			<b>9 – 12</b>	<b>7.0</b>	<b>&gt;70</b>	<b>&gt;65</b>				
<b>BAR 1 receiving standards</b>			<b>NA</b>	<b>15</b>	<b>NA</b>	<b>&gt;62.5</b>				
<b>P value</b>		<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>	<b>&lt;0.001</b>			<b>&lt;0.001</b>

\*Partial gross margin shown is calculated as an average across 2022 and 2023 seasons (grain yield x grain price – urea applied (kg /ha) /1000\*urea price). Assumed 2022 pricing: APW1 = \$380/t, ASW1 = \$370/t and urea = \$1200/tonne. Assumed 2023 pricing: Malt 2 = \$330/t, BAR1 = \$315/t, and urea = \$500/tonne.



## Summary

By implementing a strategic and longer-term approach to N management, growers can reduce N deficiency and prevent the mining of soil organic N.

A high production year in 2022 saw high N treatments (YP BoM and Decile 7) yield exceptionally well, achieving grain yields above 6.5 t/ha. All treatments had a negative partial N balance showing that soils were mined of organic N, this was reduced in high N treatments (-23.6 to -25.5) as a larger amount of N was available from fertiliser application. In 2023, several treatments yielded well including N Bank Conservative, N Bank Optimum Profit, YP Decile 5 and YP Decile 7 in an average season (275 mm GSR). Although higher yields were gained, increased N application increased screenings (%) reducing overall grain quality and receival grade. Treatments with slightly lower N application (YP Decile 5 = 34 kg N/ha) also had protein < 9%.

When reviewing cumulative results for 2022 and 2023 seasons, it is evident that District Practice (45 kg N/ha) and N Bank Conservative have been the most profitable N management strategies to date, however they do have a high negative partial N balance > 100 kg N/ha, showing soil N balances are still getting mined. Nitrogen Bank Optimum Yield and YP Decile 7 are the closest treatments to a neutral N balance of -36.8 and -46.7, respectively. It is expected that over time, more neutral to positive N balances will be observed throughout this trial.

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## Useful resources

Year 1 results of NGN Nitrogen banking trials in Southern region (2023): <https://www.farmtrials.com.au/trial/34426>