MANAGING N FERTILISER TO PROFITABLY CLOSE YIELD GAPS

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TAKE HOME MESSAGES

- Making N fertiliser N decisions based on Yield Prophet® or an environmentally appropriate N Bank target maximises profit, stops soil organic N decline and prevents accumulation of excessive mineral N.
- N decisions based on 50% Yield Prophet® or 125 kg/ha N bank strategy apply more N (60-80 kg/ha) and are $100/ha per year more profitable than the national average N fertiliser rate (45 kg/ha N).
- The most profitable strategies all have neutral to positive N balances (more N applied in fertiliser than removed in grain) indicating soil organic N is not being mined.

BACKGROUND

Australian wheat yields are only half what they could be for the rainfall received (Hochman *et al.* 2017). Nitrogen (N) deficiency is the single biggest factor contributing to this yield gap. This is also likely to be true for other non-legume crops (barley, canola and oats) and this reduces farm profitability. Alleviating N deficiency would increase national wheat yields by 40% (Hochman and Horan 2018).

On farms with no legume pastures, most of the crop N supply must come from N fertiliser. Grain legumes do not provide enough N to support yield of subsequent crops at the intensity at which they are currently grown. N fertiliser is a costly input and use of it increases cost of production and value-at-risk for growers. Growers fear that over-fertilisation will result in 'haying off', which reduces both yield and quality. There is also concern that overapplied fertiliser not used by crops is lost to the environment by leaching, volatilisation and denitrification. Consequently, efforts are made to match N fertiliser inputs to seasonal yield potential. This is difficult in southern Australia due to the lack of accurate seasonal forecasts for rainfall. The difficulty in matching N supply to crop demand and a tendency for growers to be conservative in their N inputs is the cause of the large proportion of the yield gap that can be explained by N deficiency.

In 2018 BCG and La Trobe University commenced a multi-year experiment to evaluate the potential for different N management systems to profitably close the yield gap and slow organic matter decline. 2020 was the third season of the experiment.

AIM

To evaluate different N management systems designed to profitably close the yield gap due to N deficiency and slow soil organic matter decline.

PADDOCK DETAILS

Location:	Curyo
Crop year rainfall (Nov-Oct):	2018: 200 mm 2019: 368 mm 2020: 358 mm
GSR (Apr-Oct):	2018: 138 mm 2019: 149 mm 2020: 221 mm
Soil type:	Sandy loam top-soil with clay content and calcium carbonate increasing with depth
Paddock history:	2017: Lentil

TRIAL DETAILS

Crop type/s:	2018: wheat cv. Scepter 2019: canola cv. Hyola 350 TT 2020: wheat cv. Scepter
Treatments:	Refer to Table 1
Seeding equipment:	Knife points, press wheels, 30 cm row spacing
Sowing date:	2018: 14 May 2019: 29 April 2020: 16 May
Replicates:	Four
Harvest date:	2018: 15 November 2019: 15 November 2020: 21 November

TRIAL INPUTS

N fertiliser:	Refer to Table 2 for nitrogen fertiliser applications in 2020 and *2019 BCG Season Research Results* (pages 106 to 113) for results from 2018 and 2019. All nitrogen fertiliser has been top-dressed as a single application of urea during winter.
Starter fertiliser:	2018: Urea @ 35 kg/ha at sowing (host farmer management) 2019: Granulock® Z @ 60kg/ha at sowing 2020: Granulock® Z @ 60kg/ha at sowing

The experiment was kept free of weeds and disease as per current best practice management.

METHOD

A multi-year experiment using a randomised complete block design was established in 2018 to evaluate the performance of different N management systems. There were four different systems being tested:

1. Matching N fertiliser to seasonal yield potential (Yield Prophet®)
2. Maintaining a base level of fertility using N fertiliser (N banks)
3. Replacing the amount of N removed in grain each year with fertiliser in the next season (replacement)
4. Applying national average N fertiliser rate (45 kg/ha) each season (national average)

All systems were compared to a nil control to which only starter fertiliser was applied. Within the Yield Prophet and N bank systems there were different treatments targeting different yield potentials (Table 1). 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 40 kg/ha N per t/ha wheat yield and 80 kg/ha N per t/ha canola yield (Figure 1). For the N bank treatments there were different target levels of N fertility (N banks). N fertiliser rate in these treatments were calculated as the N bank value minus soil mineral N (kg/ha) measured prior to sowing.

All gross margins were calculated using values from the 2019 SAGIT Gross Margin Guide (SAGIT 2019).

Table 1. Nitrogen management systems and treatments used in the experiments.

System	Treatment	Description
Nil	Nil	No nitrogen applied other than in starter fertiliser
Replacement	-	Amount of N removed in grain applied as fertiliser N in the following season
National average	-	National average N fertiliser (45 kg/ha N) applied each season
Nitrogen banks (kg/ha N)	100	Soil mineral N + fertiliser = 100 kg/ha N
	125	Soil mineral N + fertiliser = 125 kg/ha N
	150	Soil mineral N + fertiliser = 150 kg/ha N
Yield Prophet® probabilities	100%	Yield with lowest yielding season finish on record
	75%	Yield with lower yielding quartile season finish (decile 2.5)
	50%	Yield with median season finish (decile 5)
	25%	Yield with higher yielding quartile season finish (decile 7.5)

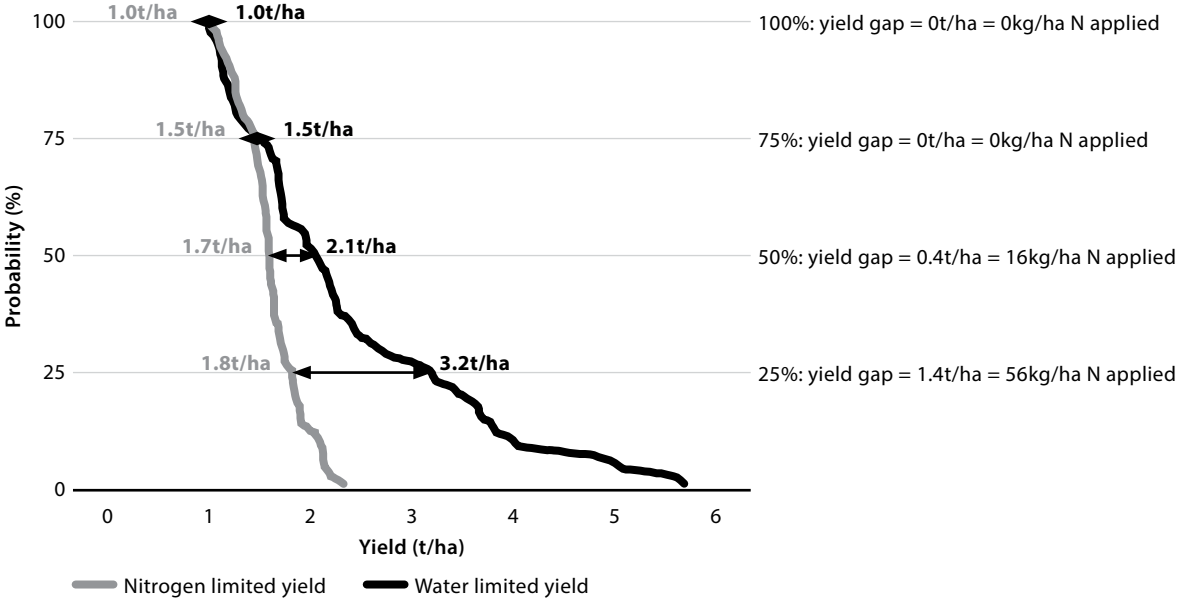

Figure 1. An example from 2018 of how Yield Prophet® is used to determine water limited potential yield given probabilities of different season outcomes and how this is used to calculate a yield gap and N fertiliser rate required to close the yield gap.

RESULTS AND INTERPRETATION

2018 & 2019 results

Please see *2019 BCG Season Research Results* (pages 106 to 113) for results from the 2018 and 2019 growing seasons.

2020 results

There were large differences between treatments in soil mineral N measured prior to sowing in 2020 (Table 2). There was a strong positive relationship between 2-year N balance (fertiliser applied minus N removed in grain in 2018 and 2019) and soil mineral N measured prior to sowing in 2020 (Figure 2). Based on linear regression of treatments with a positive N balance, 73% of fertiliser N applied in 2018 and 2019 that was not used in grain production was available as mineral N prior to sowing in 2020. This is consistent with 2019 season results.

In a relatively favourable growing season, grain yield, protein and gross margin responded positively to N supply and both were maximised in the treatment with the highest total N supply (Yield Prophet 25% – Table 2) to which 128 kg/ha fertiliser N was applied. Based on a grain protein content of 11.1%, this was also likely the only treatment in which yield was not limited by N supply (Unkovich *et al.* 2020).

Table 2. Soil mineral N measured prior to sowing, top-dressed N, crop N supply, grain yield, protein and gross margin for different treatments in the experiment in 2020.

System	Treatment	Soil mineral N (kg/ha)	Top dressed N (kg/ha)	N supply (kg/ha)	Yield (t/ha)	Protein	Gross margin ($/ha)
Nil	Nil	59	0	66	2.9	7.9	$385
Replacement	-	55	35	97	3.8	8.8	$588
National average	-	52	45	104	4.0	9.3	$605
Nitrogen banks (kg/ha N)	100	64	29	100	3.8	9.0	$573
	125	62	57	126	4.1	9.8	$626
	150	116	25	148	3.7	9.4	$573
Yield Prophet® probability	100%	59	0	66	3.2	8.0	$489
	75%	71	56	134	3.8	9.8	$563
	50%	85	84	176	4.0	10.6	$620
	25%	101	128	236	4.5	11.1	$701
Sig. diff.		**<0.001**	**-**	**<0.001**	**<0.001**	**<0.001**	**-**
LSD (P=0.05)		**20**	**-**	**20**	**0.2**	**0.6**	**-**

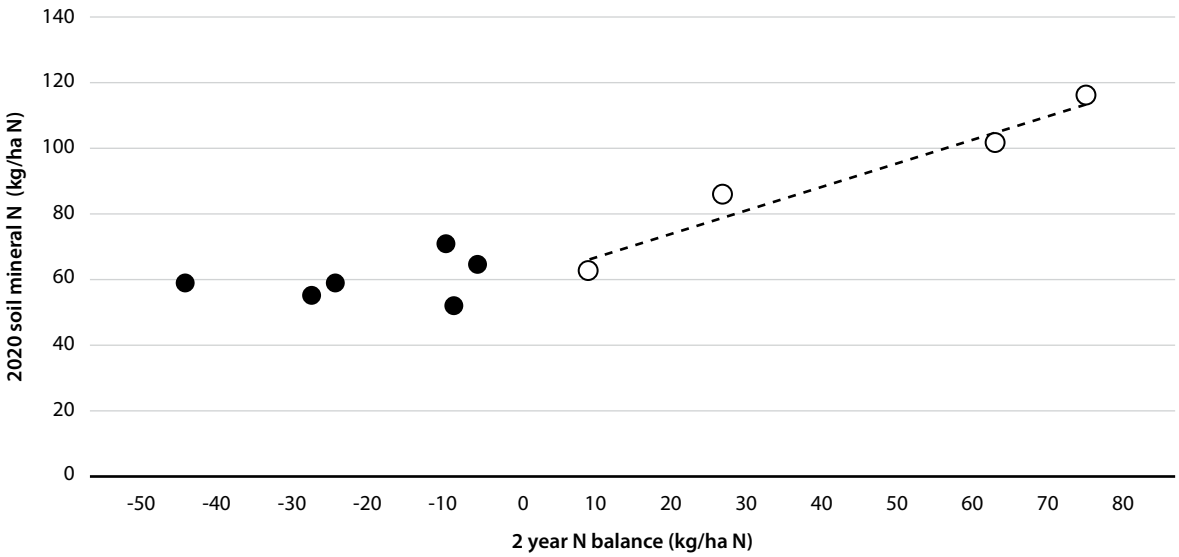

Figure 2. The relationship between 2-year N balance (2018-2019) and soil mineral N measured prior to sowing in 2020. The linear regression is fitted by least-squares regression to the positive N balance values only and is of the form y = 0.73x + 59.24, R^2 = 0.95.

3-year averages

Comparison of the different systems over the three years of the experiment shows that the Yield Prophet 50% and N Bank 125 kg/ha N treatments are most profitable, with several other treatments (Yield Prophet 25% and 75% and Nitrogen Bank 100 kg/ha) not far behind. All these treatments on average apply more fertiliser N than the national average of 45 kg/ha (Figure 3), and the Yield Prophet 50% and Nitrogen Bank 125 kg/ha have on average returned ~$100/ha per year more profit than the national average.

The two most profitable treatments also had a neutral to slightly positive 3-year N balance (Figure 4), indicating that soil organic N is not being mined and that soil organic matter is likely being maintained. This contrasts to the national average which has a 3-year N balance of -20 kg/ha N which based on the soil C:N ratio at the site of 9.7 suggests ~194 kg/ha of soil organic carbon has been lost.

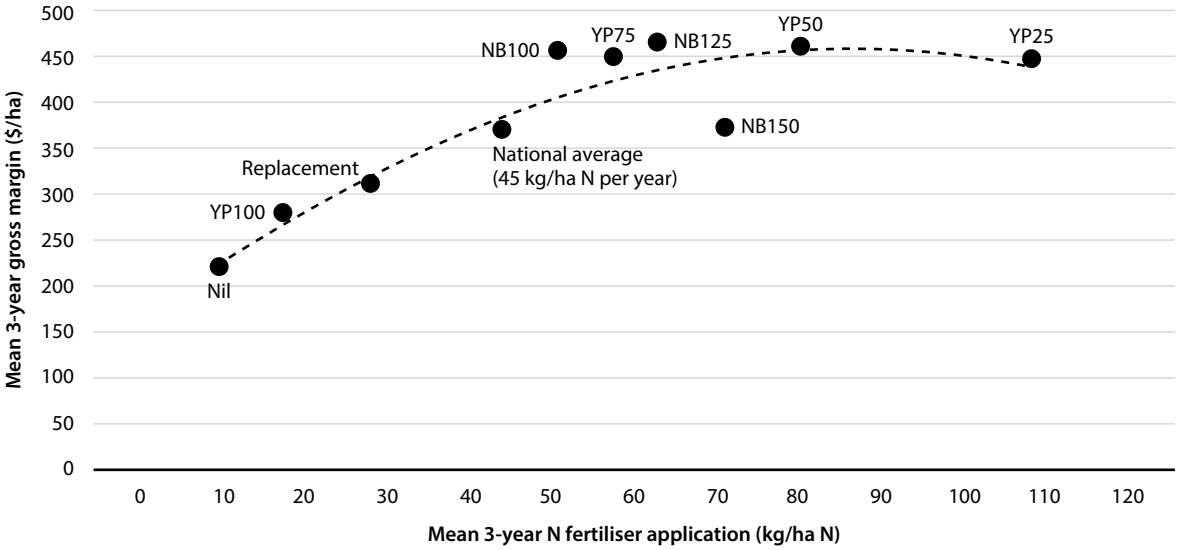

Figure 3. The relationship between mean 3-year fertiliser application and mean 3-year gross margin for the different treatments. The quadratic function fitted by least-squares regression is of the form y = -0.04x2 + 6.94x + 158.48, R^2 = 0.85.

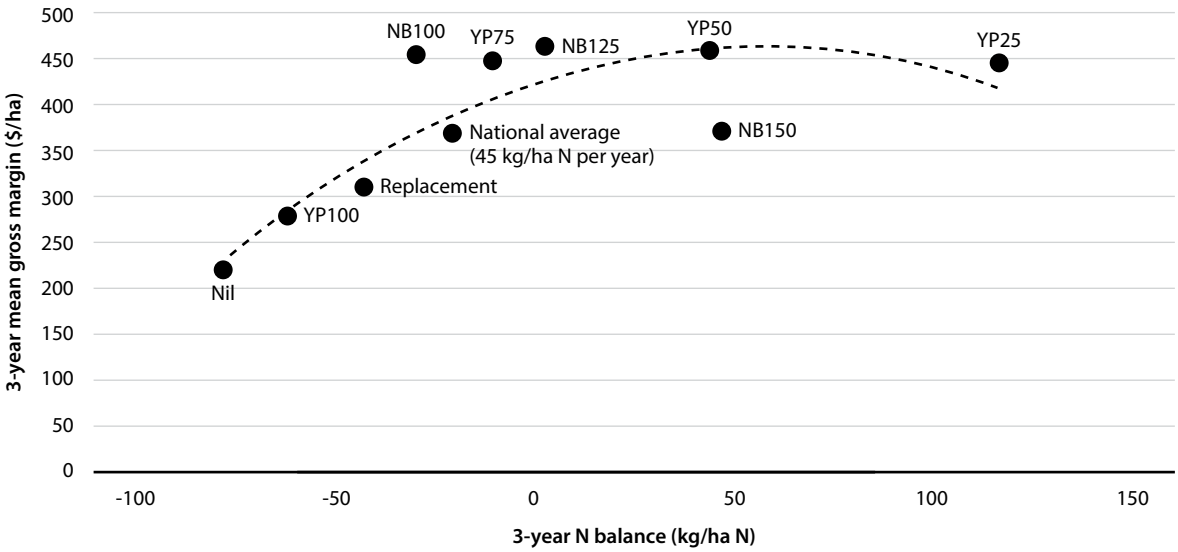

Figure 4. The relationship between 3-year N balance and 3-year mean gross margin for the different treatments. The quadratic function fitted by least-squares regression is of the form y = -0.01x^2 + 1.44x + 423.05, R^2 = 0.70.

COMMERCIAL PRACTICE AND ON-FARM PROFITABILITY

Growers should soil test and use an environmentally appropriate fertiliser N management strategy such as Yield Prophet® or Nitrogen Banks to maximise profits. In this experiment, profit has been maximised at much higher rates of fertiliser N (60-80 kg/ha N or 130-174 kg/ha urea per year) than is usually applied in the district. Long term profitability is likely to be increased by growers being less conservative with N fertiliser applications, particularly for those consistently achieving cereal grain proteins of less than 10.5% (i.e. ASW). Growers in low rainfall regions with heavy textured soils can be confident that the majority of applied N not used in year of application will remain in the soil for use in subsequent seasons and is not a lost cost.

The most profitable treatments in this experiment have neutral to slightly positive N balances, indicating a 'win-win-win' where profits are maximised, soil organic N is not mined, and excessive mineral N is not accumulated that is then susceptible to losses. Growers should check the long-term N balances of their paddocks to ensure soil organic N is not being mined. A spreadsheet to do this is available at: <https://www.bcg.org.au/understanding-crop-potential-and-calculating-nitrogen-to-improve-crop-biomass-workshop-recording/>.

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