Saving N for a rainy day: Nitrogen management after a dry finish

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Abstract
Knowing how much soil nitrogen (N) is available to crops is critical for effective nitrogen management. In 2015, six barley varieties were grown with five varying rates of nitrogen (N). The decile one rainfall season resulted in well below average yields for Victoria's Wimmera region. By October 2015 symptoms of extreme moisture stress were evident across the trial, which had a mean yield of 0.7t/ha. As a result of haying off, there was a negative relationship between N rate and yield. There was not an interaction between varieties and N rate.

In 2016 a single wheat variety was sown across all plots, with additional N applied to half of each plot. A nitrogen balance was calculated to ascertain the difference between the soil test results and estimated amount of N in residual. The 2016 wheat yields were higher where the higher N applications had been applied in 2015, showing a significant interaction between 2016 and 2015 N treatments. In paddocks where crops have hayed off, these results suggest that deep soil N testing may give a better indication of available N for a subsequent crop than paddock history.

Keywords
Barley, nutrition, decile.

Introduction
Knowing how much soil nitrogen (N) is available to crops is critical for effective nitrogen management. However, inter-seasonal variability and its effect on nitrogen supply and demand make this a continuing challenge for many growers. In particular, poor seasonal conditions can result in large amounts of applied N not being used by crops, but instead stored in the soil or lost by various processes (Küstermann et al. 2010). At the same time, applying the right amount of N, and making the most of what is already available, can be even more important in the context of tight cash flows following a dry year.

In 2015 BCG carried out a nutrition trial investigating the response of new and existing barley varieties to varied nitrogen rates at Kalkee. The trial was severely affected by dry conditions which caused plants to hay off and the results were not deemed worthy of analysis or publication. However, this failed nutrition trial provided BCG with an opportunity to examine the effect of residual or unused nitrogen inputs on a subsequent crop and to determine effective nitrogen management in paddocks where crops 'hayed off' in the previous season.

Methods
In 2015 a six-variety barley trial (cv. Commander, Compass, Flinders, GrangeR, La Trobe and Scope), with five different N rates, applied as urea (at 0, 30, 60, 90 and 120 kg N/ha) was sown at Kalkee in the Wimmera region of Victoria on 22 May 2015, in a split plot design. In 2016 a single wheat variety (Grenade CL Plus) was sown in all plots. Crop residues following harvest were retained on the plots over the summer fallow period. The trial was sown on 19 May 2016 with knife point press wheels and 30 cm row spacing, plots were 1.8 x 12m long with four replicates. Plots were then divided in half (making it a split-split plot design) and additional N was applied at GS15/22 at 41.4 kg N/ha to one half of the plots with no additional N applied to the other half. Assessments included soil testing (pre-sowing), NDVI, and grain yield and quality parameters.

Results
2015 nitrogen response trial results
The seasonal conditions in 2015, combined with the nitrogen treatments applied in this trial, were highly conducive to haying off occurring.

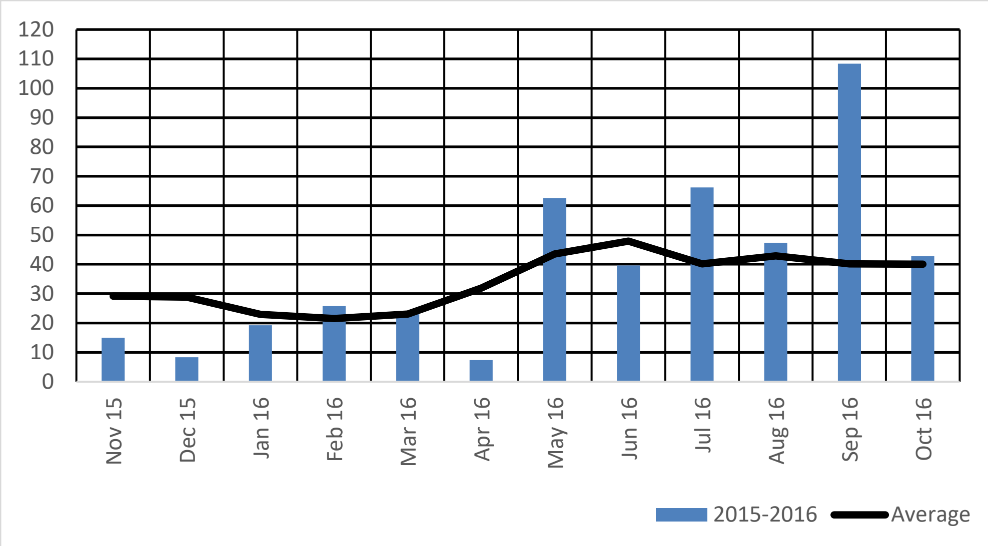

Figure 1. Rainfall (mm) at Kalkee from November 2015 through to October 2016.

Haying off refers to a premature end to grain filling typically associated with cereal crops that experience moisture stress in the later part of the season. Vigorous early growth stimulated by high N rates effectively exhausts the resources available to plants for grain fill, resulting in low yields and small, pinched grains (van Herwaarden and Richards 1998). By October 2015 the symptoms of extreme moisture stress were evident. The mean grain yields (t/ha) were N0,1.03; N30, 0.95; N60, 0.71; N90, 0.56 and N120, 0.45 with an average of 0.74 t/ha. Very high screenings were recorded in the high N treatments.

N balance and soil test results

A simple nitrogen balance is often used as a guide to the available nitrogen in a paddock at the start of the season, and to help determine required nitrogen inputs. This is calculated by subtracting the nitrogen removed in grain at harvest from available nitrogen over the growing season (comprised of a pre-sowing soil test, applied nitrogen and an estimate of mineralisation).

Soil tests undertaken before sowing in 2015 indicated 54 kg N/ha from 0-70 cm depth (65 kg N/ha to 1 m depth). An additional 22 kg N/ha was estimated from mineralisation using the formula: mineralised N = 0.15 x growing season rainfall x organic carbon (Peter Ridge, unpublished). However, this may be an overestimation due to a lack of topsoil moisture in spring (mineralisation predominantly occurs when the soils are warm); losses by leaching is unlikely due to insufficient rainfall.

The results of the nitrogen balance calculation were compared with the results from soil tests conducted prior to the 2016 season. Compass and GrangeR were the highest and lowest yielding varieties in the 2015 trial, respectively, and these varieties were used for the comparison (Table 1).

Table 1. Nitrogen balance based on 2015 paddock history, and 2016 soil test results.

Variety	2015 nitrogen balance calculation					2016 Soil test results (N kg/ha)	Difference between N balance and soil test results (N kg/ha)
	Soil Test (N kg/ha)	Mineralised (N kg/ha)	Applied N (N kg/ha)	N removed in grain (N kg/ha)	N Balance (N kg/ha)		
Compass	54	22	0	30	46	54	8
	54	22	30	40	66	42	-24
	54	22	60	37	99	62	-37
	54	22	90	34	132	65	-67
	54	22	120	27	169	67	-102
GrangeR	54	22	0	11	65	67	2
	54	22	30	14	92	63	-29
	54	22	60	5.6	130	90	-40
	54	22	90	1.9	164	107	-57
	54	22	120	1.7	194	109	-85

Pre-sowing soil tests in 2016 indicated a similar pattern of available N to the N balance calculated (i.e. higher for low-yielding plots) but differed in actual quantity (Table 1). The N balance calculation appeared to have overestimated available N in plots that had hayed off, assuming the soil tests were accurate. The 'missing' nitrogen (not indicated by soil tests) could still be contained in organic matter remaining from 2015 (where urea was top-dressed), requiring further mineralisation before becoming available to crops. Other possibilities are that it has been lost to the environment as the low rainfall recorded suggests that losses by leaching are unlikely. Nevertheless, these results strongly suggested that 2015 yield and nitrogen treatments would have an effect on crop outcomes in 2016.

Normalised Difference Vegetative Index (NDVI) taken in September (GS37), as an indicator of mid-season biomass production, showed that N applications in both 2015 and 2016 had a significant effect on growth. Most importantly, the interaction between them was also significant (P<0.001). This means that the size of the response to added N in 2016 depended primarily on the 2015 N treatment, and consequently upon the 2015 yield. Plots where high rates of N had been applied and that had subsequently 'hayed off' in 2015 had significantly higher NDVI measurements, but the response to added N in 2016 was reduced (Figure 2).

A wet spring in 2016 resulted in impressive yield results that reflected the same patterns of response shown earlier in the season. The wheat sown over plots where higher rates of N had been applied in 2015 produced higher yields, demonstrating a significant interaction between 2016 and 2015 N treatments (Figure 2). Although neither soil test results, nor the N balance, were fully consistent with estimates of N requirements for 2016, a stronger correlation between yield and soil test results (R^2=0.82) compared to N balance calculations (R^2=0.67) suggests potentially greater predictive value of the former approach.

Compass was the only barley variety grown in 2015 to have a significant effect on 2016 wheat yield, recording a lower grain yield than all varieties except for Flinders. This is likely due to Compass having the highest yield in 2015 and, consequently, the greatest N removal and lowest amount of N remaining in 2016.

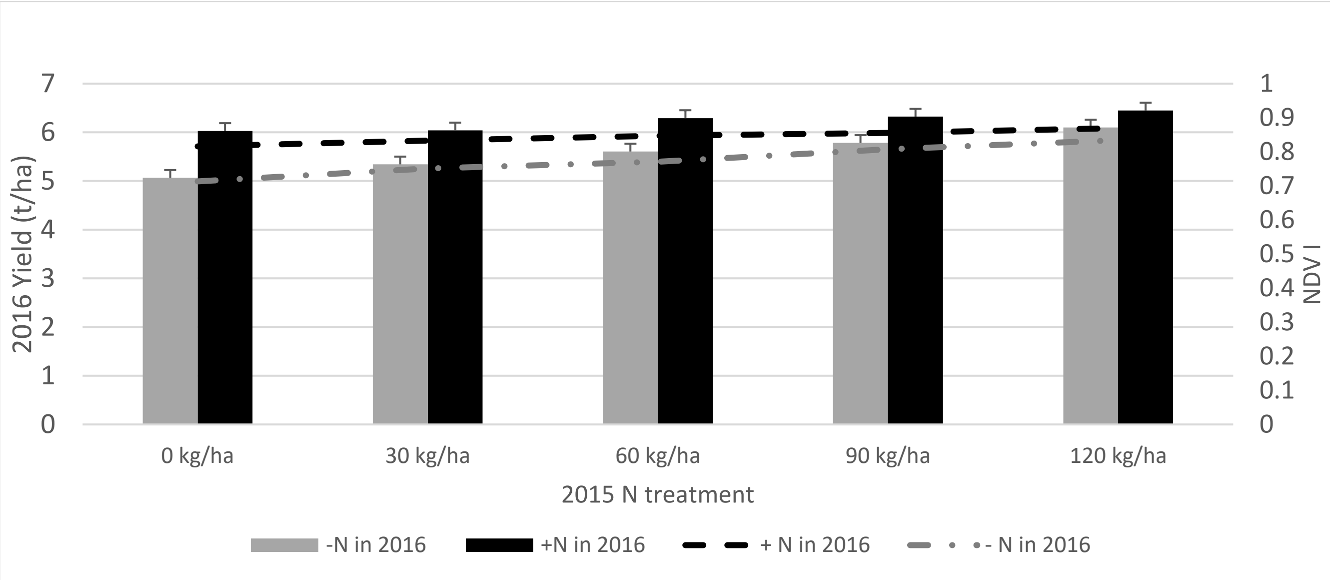

Figure 2. Average yields in 2016 by 2015 N treatment (left axis). Error bars indicate least significant difference (LSD) between 0N and +N treatments in 2016, but differences in average yield between 2015 N treatment were also all significant. Stats: P=0.001, LSD=0.16, CV = 5.5%. Right axis indicates average NDVI values for 2015 N treatment at GS37. Stats: P=0.001, LSD 0.01755, CV = 4.1%.

Grain protein levels were generally low (mean 9.8%) but were higher in plots where higher rates of N had been applied in 2015 (P<0.001). This may indicate that insufficient N was applied to reach the full yield potential in 2016, which in turn may have reduced N response more than what might otherwise have been observed. No treatment had a significant effect on screenings.

Conclusions

Our results suggest that in paddocks where crops have hayed off, deep soil N testing (to 1 m) may give a better general indication of available soil N for a subsequent crop than paddock history. While the ‘N balance calculation’ is a tried and true method, the level of accuracy of this approach appeared to be reduced substantially as the severity of ‘haying off’ increased.

Nevertheless, after a crop hays off there is significant potential yield benefits for the subsequent arising from leftover nitrogen in the next year. This benefit however is not necessarily proportional to the amount of N applied in the previous season. The strong biomass response observed mid-season following a hayed off crop, means growers need to be aware of an ongoing N response following a poor season to avoid over or under fertilising, the subsequent crop.

References

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