Evaluating impacts of applied nitrogen on grain yield and quality in wheat and barley

Mikaela Tiller and Kaidy Morgan
Hart Field-Site Group

Key findings

- At 12 weeks after application, wheat where nitrogen rates exceeded 120 kg N/ha exhibited significantly greater NDVI rating than the untreated control (UTC) and 30 kg N/ha. Higher rates of N, increased wheat biomass and vigour assisted by July rainfall favouring early crop development.
- Across the four NDVI assessment timings, Mowhawk exhibited greater NDVI ratings, indicating its early vigour and dense tillering when compared to Calibre.
- Wheat applied with 180 kg N/ha yielded more than the untreated control, however, was equivalent to all other rates of N applied.
- There were no differences observed in barley grain yield or quality across any nitrogen rate or between Commodus CL and Maximus CL.
- At higher rates of nitrogen, wheat protein and the percentage of screenings increased while test weight decreased for both varieties, indicating a potential “haying off” effect.
- Rates above 90 kg N/ha in wheat exceeded the minimum AH protein value of 13%, while all other rates including the UTC treatment exceeded the minimum APW protein value of 10.5%.

Introduction

In agricultural production systems, one of the most important yield influencing factors is nitrogen which is a major constraint to cereal production in Australia (Küstermann et al, 2010). In addition to nitrogen limitations, water availability and water use efficiency (WUE) frequently limit dryland broadacre productivity (Harries et al, 2022).

Nitrogen (N) is required abundantly during stem-elongation but has a greater requirement during reproductive phases when high protein is targeted (Angus, 2001). Additional N is required, when not water limited, to meet yield potential through correct application timing and rates, however matching crop N supply and demand when relying on variable rainfall is difficult (Angus, 2001). Applying additional N when a crop is water-limited, has been seen to cause a “haying off” effect as a result of vegetative crop growth utilising moisture and nutrient resources prior to grain fill, resulting in smaller, pinched grain with higher protein concentrations (Kirkegaard et al, 2001).

A small plot trial was conducted at Hart, SA in 2025 to evaluate the impact of increasing rates of nitrogen on haying off and grain quality parameters in wheat (*Triticum aestivum,* cv. Mowhawk and Calibre) and barley (*Hordeum vulgare*, cv. Commodus CL and Maximus CL).

Methodology

Trial design and treatments

Two varieties of both wheat and barley were selected based on suitability to the Mid North region and standardised grower benchmarks. In 2024, standard grower benchmark varieties selected were Scepter wheat and Compass barley, which were compared to Calibre and Maximus CL. In 2025, Scepter was replaced with Mowhawk, and Compass by Commodus CL after grower and advisor consultation to continue to align with grower practice across the Mid North. Comparison varieties Calibre and Maximus CL were utilised again in 2025.

Mowhawk, released by LongReach Plant Breeders, is an APW quality quick winter wheat variety, with dense tillering and an erect plant type (LRPB, 2024). Commodus CL, is a malt quality, quick-mid maturing barley variety, with good early vigour and a similar lodging tolerance to Compass (InterGrain, 2021).

At one application timing, seven nitrogen treatments were applied, starting with an untreated control (UTC), increasing in increments up to 240 kg N/ha (Table 1). Treatments were top dressed at early tillering, but before stem elongation.

Table 1. Treatment rates for 2025 wheat and barley variety X nitrogen rate comparison at Hart, SA.

Treatment Number	Rate (kg N/ha)
1 (UTC)	0
2	30
3	60
4	90
5	120
6	180
7	240

Site management and environmental conditions

Throughout the growing season the trial was managed through the application of pesticides to ensure an insect, weed and disease-free canopy.

Pre-sowing soil testing at the trial site indicated high background N (85.2 kg N/ha at 0-70 cm), likely as a result of dry conditions and following a failed wheaten hay crop in 2024. Despite being typically highly responsive to N at all decile ranges, high background N in 2025 indicated that there would only be small benefits of additional N, unless growing season rainfall exceeded Decile 3 (Hart Field-Site Group, 2025).

The 2025 growing season was characterised by below average rainfall (Decile 3, 223 mm) and this should be considered when interpreting grain quality data. The trial was not subject to stress from any other external or environmental factors.

Assessments

To measure baseline soil N, soil cores were taken across the trial prior to seeding, sampled to a depth of 70 cm and sectioned by depths of 0-10 cm, 10-40 cm and 40-70 cm for analysis. The same method was utilised for specific treatments post-harvest.

The trial was sown on May 16 with MAP (10:22) Zn 1% @ 80 kg/ha using a small-plot knife-point press wheel seeder on 23 cm row spacings. Normalised difference vegetation index (NDVI) was assessed prior to N application (July 8) and at two, eight and twelve weeks after nitrogen application utilising a handheld Greenseeker. Barley was harvested on November 7, and wheat on November 28 using a small-plot harvester. Grain yield (t/ha), protein (%), test weight (kg/hL), screenings (%) and retention (%) (barley only) were assessed post-harvest.

Trial data was analysed utilising REML spatial model (Regular Grid) in GenStat 24th Edition. Bonferroni critical difference values (Bonferroni CD) were calculated using average standard error of difference (SED) from the GenStat output and the relevant t critical value calculated in Excel. This number can be used to determine the difference required for a significant effect between treatments.

Lodging scores were to be completed two weeks prior to harvest and at harvest. However, as a result of short plant height due to growing season conditions, no lodging was observed.

Results and Discussion

Crop Biomass (NDVI)

Two weeks after application, all rates of N on wheat exhibited equivalent NDVI, however eight weeks after nitrogen application, rates above 90 kg N/ha recorded significantly greater NDVI rating than the UTC and 30 kg N/ha. Similarly, this was observed at 12 weeks after application, with rates above 120 kg N/ha achieving greater NDVI rating than the UTC and 30 kg N/ha, indicating increased biomass at higher N rates (Table 2). Above average rainfall for July favoured early crop development, however below average spring rainfall and overall lower than average growing season rainfall contributed to reduced yield potential.

Barley NDVI readings were not affected by variety selection or N rate at any of the four NDVI assessment timings (data not presented). Results were variable, particularly for NDVI 3 where a significant result was identified, however differences between treatments were unable to be extracted by statistical model (Table 2).

Table 2. NDVI values for wheat variety by N rate from 2025 nitrogen trials at Hart, SA. Shaded values in each column indicate higher biomass. Any difference between two means greater than the Bonferroni critical difference value is significant at $\alpha = 0.05$ after Bonferroni correction.

N rate (kg N/ha)		**NDVI 1**	**NDVI 2**	**NDVI 3**	**NDVI 4**	**N rate (kg N/ha)**		**NDVI 3**
Wheat	0	0.17^{ab}	0.21	0.59^{a}	0.42^{a}	Barley	0	0.77
	30	0.17^{ab}	0.23	0.63^{ab}	0.45^{ab}		30	0.82
	60	0.19^{b}	0.23	0.68^{bc}	0.48^{abc}		60	0.79
	90	0.17^{ab}	0.23	0.69^{c}	0.49^{bc}		90	0.76
	120	0.17^{ab}	0.20	0.68^{c}	0.50^{c}		120	0.81
	180	0.17^{ab}	0.23	0.70^{c}	0.51^{c}		180	0.85
	240	0.16^{a}	0.20	0.70^{c}	0.52^{c}		240	0.82
P-value (<0.05)		**0.029**	**0.012***	**<0.001**	**<0.001**			**0.025***
Bonferroni CD		**0.02**	**0.04**	**0.05**	**0.06**			**0.11**

**Results were variable, a significant result was identified, however differences between treatments were unable to be extracted by statistical model.*

Across the four NDVI assessment timings Mowhawk exhibited greater NDVI ratings, indicating its early vigour and dense tillering when compared to Calibre (Table 3).

Table 3. NDVI values for wheat nitrogen by variety trial from Hart, SA, 2025. Shaded values in each column indicate higher biomass. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

Variety	**NDVI 1**	**NDVI 2**	**NDVI 3**	**NDVI 4**
Calibre	0.16	0.19	0.63	0.47
Mowhawk	0.18	0.25	0.71	0.49
P-value (<0.05)	**<0.001**	**<0.001**	**<0.001**	**0.01**
Bonferroni CD	**0.01**	**0.01**	**0.02**	**0.02**

Grain yield

Wheat applied with 180 kg N/ha yielded more than the untreated control, however, was statistically equivalent to all other treatments (Table 5). Mowhawk yielded higher than Calibre (1.89 t/ha and 1.83 t/ha respectively) across treatments, which was consistent with observations made in the wheat variety trial completed at Hart, SA in 2025.

Table 4. Yield and grain quality values for wheat from 2025 nitrogen trials at Hart, SA. Shaded values in each column indicate best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

N rate (kg N/ha)	**Yield (t/ha)**	**Test weight (kg/hL)**	**Protein (%)**	**Screenings (%)**
0	1.78^{a}	81.8^{b}	11.5^{a}	3.8
30	1.86^{ab}	81.6^{b}	12.1^{ab}	3.6
60	1.91^{ab}	81.5^{ab}	12.7^{bc}	3.2
90	1.85^{ab}	81.1^{ab}	13.3^{cd}	4.4
120	1.83^{ab}	80.3^{a}	14.1^{de}	5.4
180	1.93^{b}	80.7^{ab}	14.0^{de}	4.5
240	1.87^{ab}	80.4^{a}	14.4^{e}	5.1
P-value (<0.05)	**0.037**	**<0.001**	**<0.001**	**0.046***
Bonferroni CD	**0.14**	**1.23**	**0.92**	**2.25**

**Results were variable, a significant result was identified, however differences between treatments were unable to be extracted*

There were no differences observed in barley grain yield across any nitrogen rate or between Commodus CL and Maximus CL (Table 5). This was consistent with results observed in the barley variety trial completed at Hart, SA in 2024 and 2025 where Commodus CL and Maximus CL yielded similarly.

Table 5. Yield and grain quality values for barley from 2025 nitrogen trials at Hart, SA.

N rate (kg N/ha)	Yield (t/ha)	Protein (%)	Retention (%)	Screenings (%)
0	2.99	14.7	51.6	10.6
30	3.04	15.5	54.1	9.0
60	2.94	15.4	48.6	11.9
90	3.16	14.3	56.1	9.5
120	3.16	13.8	59.4	7.6
180	3.09	15.7	52.2	10.3
240	3.01	15.5	50.5	10.3
P-value (<0.05)	**NS**	**NS**	**NS**	**NS**

The minimal response to differing N rates was likely due to high background nitrogen at the Hart site (Table 6). Assuming that 40 kg N/ha is required per tonne of grain for wheat and 35 kg N/ha of barley, initial soil nitrogen at Hart was sufficient to support approximately 3.5 t/ha of wheat and 4 t/ha of barley (BCG, 2014). The low yields observed indicate that crop productivity was most likely constrained by water availability in 2025; consequently, differences in applied nitrogen rates had a negligible effect on yield responses.

Table 6. Beginning of season total soil N stores accounting for mineral N, mineralisable N and sowing fertiliser for 2025 nitrogen trials at Hart, SA.

Starting soil mineral N (0-70 cm)	85.2	kg N/ha
** Mineralisable N	46.8	kg N/ha
Starting fertiliser	8	kg N/ha
Total	**140**	**kg N/ha**

*** Mineralisable N = 0.15 x OC% x GSR (for Hart 2025 = 0.15 x 1.4% x 223 mm)*

Grain quality

As the rate of nitrogen increased, protein increased for both wheat varieties, however, only rates above 90 kg N/ha exceeded the minimum AH protein value of 13%. All rates including the UTC exceeded the minimum APW protein value of 10.5% (Table 4). As nitrogen rate increased, the percentage of screenings also increased, and test weight decreased. This may indicate a potential “haying off” effect, with low yield, high protein, low test weight and high screenings being associated with this effect (Kirkegaard et al, 2001). There were no differences observed in barley grain quality across any nitrogen rate or between Commodus CL and Maximus CL (Table 5). This was consistent with results observed in the barley variety trial completed at Hart SA in 2024 and 2025.

Post-harvest N

Post-harvest soil samples sampled to a depth of 70 cm and sectioned by depths of 0-10 cm, 10-40 cm and 40-70 cm were conducted post-harvest to indicate carry-over nitrogen. Calibre and Maximus CL at four nitrogen rates (0 kg N/ha, 60 kg N/ha, 120 kg N/ha and 240 kg N/ha) were sampled.

Prior to sowing, starting N to a depth of 70 cm across the site was 85.2 N kg/ha. Soil nitrogen decreased from starting N in Maximus CL plots for rates from 0-120 kg N/ha but increased where 240 kg N/ha was applied (Figure 1). Alternatively, soil nitrogen increased for Calibre plots with rates above 120 kg N/ha and decreased from 0 and 60 kg N/ha. Remaining soil N was greater across all rates for wheat when compared to the same rate in barley. Yield benefits for the subsequent crop following a poor finish and a “hayed off” crop may be observed; however, growers should be cautious the following year to avoid over or under fertilising (Browne and Ie, 2017).

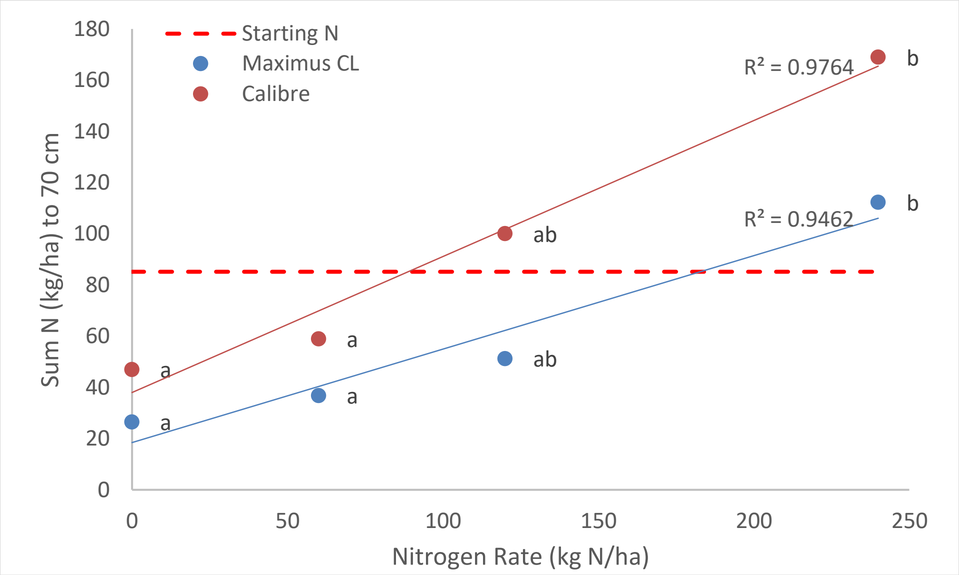

Figure 1. Soil nitrogen post-harvest of Maximus CL (P-value = 0.016, Bonferroni CD = 74.6 N kg/ha) and Calibre (P-value= 0.003, Bonferroni CD = 80.9 N kg/ha) sum of N (0-70 cm) across four nitrogen regimes: 0 kg N/ha, 60 kg N/ha, 120 kg N/ha and 240 kg N/ha. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

Summary

Decile 3 (223 mm) GSR at Hart in 2025 affected yield potential and quality across the trial site. Wheat applied with 180 kg N/ha achieved a yield of 1.93 t/ha which was significantly greater than the 1.78 t/ha achieved by the untreated control, however, was equivalent to all other N treatments. As the rate of nitrogen increased in wheat, protein percentage and the percentage of screenings increased while test weight decreased, indicating a potential “haying off” effect. There were no differences observed in barley grain yield or quality across any nitrogen rate or between Commodus CL and Maximus CL.

Acknowledgments

The Hart Field-Site Group would like to acknowledge the generous support of our sponsors who provide funding that allows us to conduct this trial. Proceeds from Hart's ongoing commercial crop also support Hart's research and extension program. We would like to thank the various organisations who provided product and seed to conduct this trial.

This trial is funded by

References

Angus JF., 2001. Nitrogen supply and demand in Australian agriculture. Australian Journal of Experimental Agriculture 41, 277–288. https://doi.org/10.1071/EA00141

Birchip Cropping Group (BCG). 2014. Nitrogen management in season. Available at: https://www.bcg.org.au/

Browne, C. and Ie, S., 2017. Saving N for a rainy day: nitrogen management after a dry finish. Available at https://www.agronomyaustraliaproceedings.org/

Harries, M., Flower, KC., Renton, M. and Anderson, GC. 2022. Water use efficiency in Western Australian cropping systems. Crop & Pasture Science 73, 1097-1117. https://doi.org/10.1071/CP21745

Hart Field-Site Group. 2025. HART BEAT. Issue 67; July 9, 2025. Available at https://www.hartfieldsite.org.au/pages/resources/hart-beat-newsletters.php

InterGrain. 2021. Commodus CL. Available at https://intergrain.com/variety/commodus-cl/

Kirkegaard, JA., Howe, GN. and Pitson, G. 2001. Agronomic Interactions between Drought and Crop Sequence. Available at https://www.agronomyaustraliaproceedings.org/

Küstermann, B., Christen, O. and Hülsbergen, K. 2010. Modelling nitrogen cycles of farming systems as basis of site-and farm-specific nitrogen management. Agriculture, ecosystems & environment 135, no. 1-2 70-80. https://doi.org/10.1016/j.agee.2009.08.014

LongReach Plant Breeders. (LRPB). 2024. Mowhawk. Available at https://www.longreachpb.com.au/products/mowhawk