Increasing grain protein with delayed applications of fertiliser nitrogen

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Abstract
Low grain protein can cause downgrading of barley from Malt1 (GIWA Malt1 protein window is 9.5-12.8%). With increasing productivity and decreasing nitrogen (N) supply available from the soil (primarily due to lack of legumes in the crop rotation), growers need to increase their fertiliser N applications to produce adequate protein levels. In addition to increasing N rate, growers can improve their fertiliser effectiveness by changing the timing of N application. In this study, shifting N from seeding and mid-tillering to the stem elongation period consistently increased grain protein, although was often associated with increased screenings and for some treatments reduced grain yield. Most delayed N strategies (except N timings 2 and 4) provided a protein increase of 0.5-1.0% relative to the strategy of ⅓ N at seeding, mid tillering and stem elongation (N timing 1 – current practice control) in at least three of the four sites. Only two delayed N strategies, N timing 2 and 3, did not affect grain yield at any site. Compared to N timing 1 moving the ⅓ N from mid-tillering to stem elongation (N timing 2) increased grain protein at only two sites whereas applying the bulk of the N at stem elongation (N timing 3) increased grain protein at all four sites. Both strategies, however, increased screenings (at two and three sites respectively), though did not negatively impact on hectolitre weight or grain brightness. The grain protein increase of the other delayed N strategies may often have been larger than N timings 2 and 3 but came at a risk of higher screenings, lower hectolitre weight or lower grain yield (site specific). The best of the other strategies evaluated was N timing 10 (⅓ N at seeding, stem elongation and flag leaf emergence), which increased protein at three sites, had no impact on screenings or hectolitre weight at any site, although did reduce yield and brightness at one site.

Key Words
Nitrogen timing, grain protein, stem elongation, flag leaf emergence, barley

Introduction
On average, WA produces 3.5 Mt of barley (average yield of 2.5 t/ha) (ABS 2018) with over 90% of that area sown to varieties with a malt classification (BVSG 2018). However, grain protein concentration in barley has declined alongside the improvements in grain yield achieved in recent years, and large quantities of WA's barley crop is not achieving grain protein levels required by the market. The lack of suitable legumes within the rotation and the difficulty of matching N to yield potential on WA's soils (of often low-water holding capacity and varying intensities of terminal drought) limit growers' ability to use rotation and N rate *per se* to manage grain protein effectively. Research in WA has shown that targeting N application at around stem elongation can increase barley grain protein by 0.5-1.0% compared to the same rate of N applied at seeding, with little impact on grain yield (Paynter 2005, Malik and Paynter 2015, Paynter 2017, Paynter and Malik 2017). This study assessed even later application timings (particularly N applications from stem elongation to awn peep) on grain protein, grain yield and other receival standard traits relevant to WA barley growers.

Methods
Four experiments were conducted in 2018 to compare the response of two two-row, spring malt barley varieties, RGT Planet and Spartacus CL, to different N management strategies. The trials were in medium to high rainfall locations at Yerecoin (30.961 S, 116.476 E), Brookton (32.367 S, 116.948 E), Kojonup-W (33.889 S, 116.784 E) and Wittenoom Hills (33.429 S, 122.171 E). Herbicides (knockdown and incorporated by seeding) were applied before seeding, and the seed (treated with EverGol Prime, CropCare Jockey and Emerge 600) was direct-drilled at 2-3cm depth (target establishment of 150 plants/m^2) into canola stubble with a small plot air-seeder using knifepoints and press wheels. Summit Gusto (treated with Uniform) was banded below the seed at 100 kg/ha (supplying 10 kg N/ha, 12 kg P/ha and 14 kg K/ha). Nitrogen (N) was top-dressed as urea at varying rates (N rate) at various timings (N timing). N rates (totalling all banded and top-dressed N) were 60, 90 and 120 kg N/ha. N timings were seeding, mid-tillering (four weeks after seeding, WAS), first node detectable (Z31), third node detectable (Z33), flag leaf emergence (Z37) and awn

emergence (Z49) (Table 1), with each N timing applied relative to the growth stage of each variety, with RGT Planet typically 3-5 days later to awn emergence than Spartacus CL (BVSG 2018). Each site was sown as six banks of 10 m plots with two banks per replicate and three replications per treatment. Weeds and leaf diseases were controlled as required. Grain yields were recorded at harvest and cleaned (>1.5mm), and de-awned grain sub-samples were assessed for hectolitre weight (kg/hL), screenings (% < 2.5 mm), grain protein (%, dry basis) and grain brightness ('L*').

Data were analysed for the main effects of variety, N rate and N timing (and their interactions) within Genstat (VSN International 2018) with a design structure of 2 variety x 3 N rate x 11 N timing and a block structure of (rep+colrep)/(variety.N rate)/N timing. Spatial trends in the yield data influenced the N timing effect with data and statistics for grain yield presented based on a linear mixed model with spatial trend component. N timings 2-11 were compared to N timing 1 using the site LSD (p=0.05).

Table 1. The proportion of the total N applied at each of the six potential dates of application.

N timing	Seeding	4WAS	Z31	Z33	Z37	Z49
1	⅓ Total N	⅓ Total N	⅓ Total N	-	-	-
2	⅓ Total N	-	⅔ Total N	-	-	-
3	10 N	-	Balance N	-	-	-
4	⅓ Total N	-	⅓ Total N	⅓ Total N	-	-
5	10 N	-	½ Balance N	½ Balance N	-	-
6	10 N	-	-	Balance N	-	-
7	10 N	-	Remaining N	-	10 N	-
8	10 N	-	Remaining N	-	25 N	-
9	10 N	-	⅓ Balance N	⅓ Balance N	⅓ Balance N	-
10	⅓ Total N	-	⅓ Total N	-	⅓ Total N	-
11	⅓ Total N	-	⅓ Total N	-	-	⅓ Total N

Results

Variety

RGT Planet and Spartacus CL differed in their grain yield and screenings at only one site but did differ in their other kernel characteristics in at least three of the four sites (Table 2). On average, RGT Planet grain had a lower hectolitre weight than Spartacus CL by 4 kg/hL, had 0.9% less protein and was slightly brighter (0.4 'L*') (data not shown). The grain protein yield of RGT Planet was lower than Spartacus CL at two sites.

N rate

Increasing N rate resulted in increased grain protein concentration and grain protein yield at all sites and increased screenings at all sites except Kojonup-W (Table 2). N rate also increased grain yield and reduced hectolitre weight at both Yerecoin and Wittenoom Hills but did not affect grain brightness. N rate did not interact with variety for any traits except for grain yield at Yerecoin and Wittenoom Hills (RGT Planet was less responsive than Spartacus CL), grain protein at Wittenoom Hills (RGT Planet was more responsive than Spartacus CL) and grain protein yield at Yerecoin (Spartacus CL was more responsive than RGT Planet).

N timing

Altering the timing of the N application influenced screenings, grain protein and grain protein yield at all sites, and grain yield (except Brookton), hectolitre weight and brightness (both except Kojonup-W) at three sites (Table 2). There was an interaction of N timing with the site for all six traits presented in Table 2, so results for grain yield, grain protein, hectolitre weight and screenings are presented for each site in Table 3.

Of the ten alternative N timing strategies that were compared to N timing 1 (⅓ N applied at each of seeding, 4WAS and Z31), five resulted in reduced yield at Yerecoin, seven reduced yield at Kojonup, and two reduced yield at Wittenoom Hills (Table 3). N timing did not significantly impact yield at Brookton. Of the treatments that reduced yield at multiple sites, N timing 6 and N timing 11 reduced yield at three sites, while N timing 8 and N timing 9 reduced yield only at Yerecoin and Kojonup-W. Generally, the treatments that reduced yield at Yerecoin were those that withheld a reasonable proportion of N until Z37 or after, while the treatments that reduced yield at Kojonup-W withheld a reasonable proportion of N until Z33 or later. N timings 2 and 3 did not influence grain yield relative to timing 1 at any site.

Grain protein was influenced by N timing at all sites, with seven of the alternative N timing strategies increasing grain protein compared to N timing 1 at all sites. Only N timing 4 (only significant at Kojonup-W), N timing 2 (only significant at Brookton and Kojonup-W) and N timing 10 (not significant at Yerecoin) did not increase protein at all sites. Screenings were influenced by N timing at all four sites, with N timings 5, 6, 7 and 9 increasing screenings at all sites, while N timings 3 (except Kojonup-W) and 4 (except Yerecoin) increased screenings at three sites. N timings 10 and 11 did not increase screenings at any sites.

Table 2. Number of sites where variety, N rate, N timing and their interactions were significant ($p<0.05$).

Factor	Grain yield (t/ha)	Hectolitre weight (kg/hl)	Screenings (%<2.5mm)	Grain protein (%, db)	Grain brightness ('L*')	Grain protein yield (kg/ha)
Variety (V)	1	4	1	4	3	2
N rate (N)	2	2	3	4	0	4
V x N	2	0	0	1	0	1
N timing (NT)	3	3	4	4	3	4
V x NT	1	1	3	2	1	1
N x NT	1	0	0	1	1	2
V x N x NT	2	0	1	0	0	0

Table 3. The change in grain yield (t/ha), grain protein (%), hectolitre weight (kg/hL) and screenings (% < 2.5mm) due to changes in N timing, relative to N timing 1 at four sites and averaged across varieties (RGT Planet and Spartacus CL) and N rates (60N, 90N and 120N). Ye=Yerecoin, Br=Brookton, Ko=Kojonup-W, WH=Wittenoom Hills. Bold values indicate significant difference from N timing 1.

N timing	Grain yield (t/ha)				Grain protein (%, db)				Hectolitre weight (kg/hL)				Screenings (% < 2.5mm)			
	Ye	Br	Ko	WH	Ye	Br	Ko	WH	Ye	Br	Ko	WH	Ye	Br	Ko	WH
1 (value)	5.14	4.46	3.56	5.39	8.75	10.38	10.5	9.81	72.0	74.3	72.2	70.2	14.8	11.0	3.3	4.6
2	-0.06	-0.08	-0.11	+0.00	+0.26	**+0.46**	**+0.64**	+0.19	+0.1	-0.3	-0.1	-0.2	+2.7	**+4.1**	+0.4	**+1.0**
3	-0.13	-0.02	-0.11	-0.07	**+0.68**	**+0.58**	**+0.87**	**+0.48**	-0.3	-0.3	+0.0	-0.2	**+9.0**	**+4.2**	+0.2	**+1.5**
4	-0.14	-0.04	**-0.14**	-0.10	-0.01	+0.06	**+0.89**	+0.24	+0.1	-0.3	+0.1	-0.3	+3.8	**+3.2**	**+1.2**	**+0.9**
5	-0.10	+0.12	**-0.21**	-0.08	**+0.65**	**+0.72**	**+0.71**	**+0.67**	-0.5	**-0.5**	-0.4	**-0.4**	**+9.5**	**+6.6**	**+1.0**	**+2.4**
6	**-0.54**	-0.05	**-0.21**	**-0.20**	**+0.49**	**+0.95**	**+1.17**	**+0.64**	**-0.7**	**-0.5**	-0.1	**-0.3**	**+20.4**	**+8.7**	**+2.2**	**+2.6**
7	-0.06	+0.06	**-0.15**	-0.05	**+0.58**	**+0.93**	**+1.00**	**+0.49**	-0.0	**-0.5**	-0.2	**-0.4**	**+7.2**	**+5.6**	**+1.0**	**+1.6**
8	**-0.23**	+0.00	**-0.15**	-0.10	**+0.58**	**+1.18**	**+1.43**	**+0.64**	-0.4	**-0.5**	+0.0	-0.2	**+9.9**	**+4.7**	+0.6	**+1.4**
9	**-0.32**	+0.03	**-0.18**	-0.11	**+0.67**	**+1.02**	**+1.23**	**+0.77**	-0.6	-0.1	-0.3	-0.3	**+9.4**	**+4.1**	**+1.2**	**+2.7**
10	**-0.15**	-0.01	-0.06	-0.10	+0.28	**+0.71**	**+0.81**	**+0.47**	+0.2	+0.3	+0.0	-0.1	+3.5	-0.2	+0.8	+0.4
11	**-0.24**	-0.10	**-0.14**	**-0.31**	**+0.44**	**+0.85**	**+0.88**	**+0.62**	**+1.0**	+0.1	+0.2	**+0.4**	-1.0	+0.5	-0.0	**-0.9**
p-value	<0.001	n.s.	0.047	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	n.s.	<0.001	<0.001	<0.001	<0.001	<0.001
LSD (0.05)	0.14	-	0.12	0.13	0.32	0.33	0.39	0.25	0.6	0.4	-	0.3	4.1	2.4	0.9	0.7

N timing significantly influenced hectolitre weight at three sites (Table 3). Relative to N timing 1, hectolitre weight was reduced at three sites by N timing 6, reduced at two sites by N timings 5 and 7 and increased at two sites by N timing 11. Grain brightness was influenced by N timing at three sites, although changes were small (< 1.0 'L*') and inconsistent across treatments (data not shown). N timing significantly influenced grain protein yield at all sites, and relative to N timing 1 was increased by N timing 8 at four sites, and at three sites for N timing 3 (except Brookton) and N timings 5, 7 and 9 (except Kojonup-W) (data not shown).

RGT Planet and Spartacus CL responded similarly to N timing across most sites for all traits except screenings (significant at three sites) and grain protein (significant at two sites). Where N timing influenced screenings, particularly at Yerecoin and Brookton, these changes were larger in Spartacus CL than RGT Planet. N timing increased grain protein slightly more in RGT Planet at Brookton and Wittenoom Hills.

Discussion

N timing 1 (⅓ of total N split across seeding, mid-tillering and stem elongation) roughly reflects grower practice in WA, where often ⅔ or more of the recommended fertiliser N is applied in the period from seeding to six weeks after seeding. This study compared N timing 1 to other less-conventional N timing strategies (including applications as late as awn emergence, Z49) and confirmed that moving a higher proportion of applied N to later in the season increased grain protein (Table 3). However, some of the strategies also increased the potential negative impacts of delayed N, such as reduced grain yield and increased screenings.

Moving the ⅓ of N allocated to mid-tillering of N timing 1 to Z31, Z33, Z37 or Z49 (N timings 2, 4, 10 and 11, respectively) influenced yield, protein and screenings. While N timing 11 reduced yield and N timings 2 and 4 inconsistently increased protein, N timing 10 increased grain protein at three sites while reducing yield at just one site and did not impact screenings. Therefore, top-ups of N at flag leaf emergence are a potential strategy for increasing grain protein without reducing yield or detrimentally increasing screenings.

Less conventional strategies that involved applying just 10N at seeding, with the rest applied from Z31 to Z37 (N timings 3, 5, 6, 7, 8 and 9) always increased protein compared to N timing 1 but also almost always increased screenings and sometimes reduced yield. The risk of a yield reduction was reduced if most of the top-up N was applied by Z31 (N timings 3 and 7). While the screenings increases associated with N timings 3, 5, 6, 7, 8 and 9 were inconsequential at the two sites with softer finishes (Kojonup-W and Wittenoom Hills), the associated screenings increases of those timings sometimes resulted in grain exceeding the GIWA Malt1 limit of 20% screenings at Brookton and Yerecoin. In scenarios where the likelihood of high screenings is usually low (reliable grain filling rainfall and plump grained varieties), grain protein can be comfortably increased with little yield downside by ensuring that the majority of the fertiliser N is applied by Z31 (N timing 3), with possible top-ups at Z37 (N timings 7 and 8) to maximise grain protein.

Conclusion

Previous studies have assessed the impact of N timing strategies as late as Z31 over multiple seasons, finding that moving a greater proportion of N from seeding to Z31 increased grain protein with minimal yield impact, although with an associated increase in screenings (Malik and Paynter 2015, Paynter 2017, Paynter and Malik 2017). This study extended the timing of N application through stem elongation and as late as awn emergence. Overall, moving a higher proportion of N application from pre-stem elongation (seeding and tillering) to the start of stem elongation or later consistently increased grain protein and screenings across the four sites. N timing 10 (⅓ of N at seeding, Z31 and Z37) was the most effective strategy for increasing grain protein without impacting screenings. Applying 10N at seeding and the rest at Z31 or later consistently increased protein and screenings, with N timings 3, 5 and 7 having the least impact on yield, and N timings 8 and 9 giving the highest protein increase. Additional benefits of delaying N include improved understanding of the potential of the season to help determine N rate and confidence that late top-ups into stem elongation are still useful for producing yield and protein. The major downside, increased screenings risk, can be offset by sowing plumper grained varieties that have a lower screenings risk. Given the importance of rainfall and plant available water on nitrogen uptake, yield potential and grain quality, it will be important to assess the response of barley to these later N timings over multiple seasons.

References

ABS (2018). Agricultural Commodities, Western Australia for period 2013-2017. Australian Bureau of Statistics, abs.gov.au.

BVSG (2018). 2019 Barley variety sowing guide for Western Australia – Bulletin 4895. Eds. BH Paynter, GC Trainor, JK Curry. DPIRD, Perth

Malik RS and Paynter BH (2015). Nitrogen rates and timing for new malting barley varieties. 2015 Agribusiness Crop Updates, Perth WA, 24-25 Feb 2015.

Paynter BH (2005). Low protein management in Gairdner and Baudin barley. *In* Proceedings of the 12th Australian Barley Technical Symposium, Hobart, Tas, 10-13 Sept 2005.

Paynter BH (2017). What influence does nitrogen timing have on La Trobe's ability to meet malt barley specifications? 2017 GRDC WA Grains Research Update, Perth WA, 27-28 Feb 2017.

Paynter BH and Malik RS (2017). Effect of nitrogen timing on barley performance in a season with a dry start, wet middle and dry finish (aka 2015 season). 2017 GRDC WA Grains Research Update, Perth WA, 27-28 Feb 2017.

Acknowledgements

The Department of Primary Industries and Regional Development and the Grains Research and Development Corporation (DAW00224) supported this research. Shelley Hall, Rod Bowey, Helen Cooper and Field Research Units at Wongan Hills, Northam, Katanning and Esperance provided technical support.