

Nitrogen rates and timing for new malting barley varieties

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Key messages

- In this study (site yields > 3 t/ha), nitrogen (N) rate and N timing both influenced grain protein concentration (GPC), with the impact of N rate on GPC modified by N timing at three of the four sites.
- N rate influenced lodging and grain yield independently of N timing at three of the four sites.
- The absolute effect of N rate on lodging, grain yield and GPC was larger than the influence of N timing.
- Varieties responded similarly to N rate in their lodging, grain yield and GPC response at three of the four sites.
- Varieties responded similarly to N timing in their lodging, grain yield and GPC response at all sites (except at one site for lodging).
- Bass, Commander and Granger did not differ in their grain protein concentration (GPC) when differences in their grain yield were accounted for.
- This study suggests that similar N management strategies can be used for Bass, Commander and Granger to maximise their grain yield and optimise their GPC.

Background and Aims

The current malt barley receival standards for grain protein concentration (GPC) (on a dry basis) are between 9.5-12.5% for delivery as Malt1 and between 9.0-12.8% for delivery as Malt2. Any malt barley grain with a GPC outside those ranges is received as feed because of reduced brewing performance (i.e. low alcohol yield or low foam stability). As the difference between malt and feed grade prices can be significant, it is important that appropriate crop management practices are implemented to improve the probability of achieving receival grade GPC.

GPC is influenced by variety, crop management and the environment. In an analysis of commercial malt barley varieties Graham *et al* (2013), Porker and Wheeler (2013) and Paynter and van Burgel (2014) reported that Commander consistently had a lower GPC than varieties such as Baudin and Granger (at any given grain yield) whilst Bass had a higher GPC. The difference in GPC between Commander and Bass was around 1%, after removing the influence of grain yield (Paynter and van Burgel 2014).

Do varieties with an inherent low GPC require a different rotation and nitrogen (N) management plan than varieties inherently high in GPC to maximise yield potential and meet protein receival standards? Porker and Wheeler (2013) proposed that earlier sowing and delayed N may be the best strategy for achieving optimum yield and protein in low GPC varieties like Commander in higher yielding environments. However, increased up-front N or sowing into high nitrogen fertility paddocks may increase the risk of lodging, an issue to which Commander is prone to.

Since N levels in the soil and N fertilisation are major factors that affect GPC in a given variety, the challenge is to understand how tactical management of N fertiliser rates and timing can be used to achieve the targeted GPC of varieties which differ in their inherent GPC. The aim of this paper is to report on the assessment of three varieties differing in their inherent GPC – Commander (low), Granger (normal) and Bass (high) – to determine if they require different N management (rate and timing) strategies to meet industry receival standards for GPC.

Table 1. Site, soil type, previous crop, growing season rainfall (May-Oct 2014) and soil test (0-10 cm) data for four N management trials conducted in Western Australia.

Site	Location	Previous crop	Date of seeding	GSR (mm)	Mineral N (kg N/ha)	Total N (%)	Organic C (%)	pH (CaCl ₂)
14GS25	Katanning	canola	30-May-14	372	59	0.21	2.3	4.6
14GS26	Katanning	lupin	30-May-14	372	81	0.25	2.5	5.5
14GS27	Kojonup-W	canola	06-Jun-14	400	79	0.43	3.7	5.2
14NO36	York	canola	15-May-14	341	36	-	2.1	5.7

Method

Four trials were conducted to compare the response of three malting barley varieties (Bass, Granger and Commander) to 17 different N rate and timing strategies. The trial sites were located at Katanning (two different cropping histories), Kojonup-W and York (Table 1). Soil type of 14GS25 was a brown shallow sandy duplex, 14GS26 a dark brown deep loamy duplex, 14GS27 a yellow-brown deep sandy duplex and 14NO36 a brown shallow loamy duplex.

Trials were sown as a fully randomised cyclic design with variety as whole plots and applied nitrogen treatments randomised as subplots with N rates + N timing combination, sown in six banks with two banks per replicate. The trials were direct-drilled with a small plot air-seeder with press wheels. Barley seed (target establishment of 150 plants/m²) was placed at 2–3 cm depth. CSBP Super CZM was banded below the seed at 120 kg/ha. Selected treatments received N (top dressed as urea) at varying rates (N rate) at three timings (N timing). N rates were 0, 15, 30, 60 or 120 kg N/ha and N timings were 0 weeks after seeding (WAS), 5 WAS (tillering) and 10 WAS (stem elongation). N was applied either as a single application at one of the three timings or evenly split over the three timings. Lodging scores (9 to 0) were recorded as close to harvest as possible. A lodging score of 9 = upright plants with no lodging. As the lodging score decreases towards 0, the degree of lodging increases. A lodging score of 0 = whole plot fully lodged and effectively un-harvestable. Grain yields were recorded at harvest and cleaned (> 1.5 mm) samples were used to determine receival standard grain quality measurements. Only the GPC quality data is presented in this paper. Data was analysed in Genstat with a block structure of rep+colrep and a treatment structure of variety*(x/(N rate*N timing)) where 'x' denotes nil or applied nitrogen treatments. Grain protein deviation (GPD) for all N treatments across all four sites was analysed with Genstat using the methods of Paynter and van Burgel (2014).

Table 2. Analysis of variance for main effects (variety, N rate, N timing) and their interactions at the four sites. Significance: * = p<0.001, ** = p<0.01, * = p<0.05 and n.s. = not significant.**

Trait Site	Lodging (9-0)				Grain yield (t/ha)				Grain protein (% db)			
	14GS25	14GS26	14GS27	14NO36	14GS25	14GS26	14GS27	14NO36	14GS25	14GS26	14GS27	14NO36
Variety (V)	***	***	***	***	***	**	***	***	***	n.s.	***	n.s.
N rate	*	**	*	***	***	*	***	***	***	***	***	***
N timing	n.s.	n.s.	**	**	n.s.	n.s.	***	**	***	*	***	***
V x N rate	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.	*
V x N timing	n.s.	n.s.	n.s.	***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
N rate x N timing	n.s.	n.s.	n.s.	***	n.s.	n.s.	n.s.	*	***	n.s.	***	***
V x N rate x N timing	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.

Table 3. Differences in the lodging score, grain yield and grain protein of three barley varieties across all N treatments at four sites in 2014. Data separated by Fishers unprotected LSD (p=0.05).

Site	14GS25			14GS26		
Variety	Bass	Commander	Granger	Bass	Commander	Granger
Lodging (9-0)	7.7 b	7.3 a	7.5 b	6.5 b	4.6 a	6.8 b
Grain yield (t/ha)	3.34 b	3.24 b	3.08 a	5.40 a	5.42 a	5.65 b
Grain protein (% db)	10.19 b	10.21 b	9.87 a	11.50 a	11.26 a	11.34 a
Site	14GS27			14NO36		
Variety	Bass	Commander	Granger	Bass	Commander	Granger
Lodging (9-0)	7.2 b	6.9 a	8.0 c	7.9 c	6.4 a	7.0 b
Grain yield (t/ha)	4.58 a	4.94 b	5.15 c	3.69 a	3.67 a	3.88 b
Grain protein (% db)	9.68 b	9.13 a	9.53 b	9.18 a	9.01 a	9.08 a

Results

Lodging

Varieties differed in their lodging resistance (Tables 2 and 3). Across all treatments the average lodging score of Bass and Granger was 7.3 and Commander 6.3.

Lodging increased as N rate increased at each site, although the change at 14GS27 was small and only evident with the highest rate of N (Figure 1). There was no variety x N rate, variety x N timing or N rate x N rate timing interaction at 14GS25, 14GS26 and 14GS27, but there was at 14NO36. At 14NO36 the increase in lodging due to N was larger in Commander than in Bass and Commander (Figure 2). At that site for N applications up to 60 N there was no influence of timing on lodging, whereas with 120 N there was significantly more lodging in the plots that received their entire N at 0 or 5 WAS compared to 10 WAS (data not shown).

N timing only influenced lodging at two sites (14GS27 and 14NO36) (Table 2 and Figure 3), but its impact was less than the impact of N rate. Delaying N from 0 to 10 WAS did not significantly reduce the lodging risk, except at 14GS27. Splitting N also caused no major change in lodging risk compared to all the N applied at 0 WAS.

Grain yield

Varieties differed in their grain yield at these high yielding sites (site yields > 3 t/ha) (Tables 2 and 3). Across N treatments Granger was higher yielding than Bass and Commander by 0.3 t/ha and 0.2 t/ha respectively at three of the four sites and 0.3 t/ha lower yielding than Bass and 0.2 t/ha lower than Commander at one site.

N rate influenced grain yield, with a different yield response present at each site (Figure 1). 14GS26 (lupin stubble) was the only site with a reduction in grain yield above 30 N. The yield response plateaued at 60 N in 14GS25 and 14NO36, but continued to 120 N in 14GS27. There was no variety x N rate, variety x N timing or N rate x N rate timing interaction at 14GS25, 14GS26 and 14GS27. At 14NO36 there was a variety x N rate and an N rate x N rate timing interaction. At 14NO36 Bass was more responsive to N than either Commander or Granger (Figure 2), but their response to N timing was the same.

N timing only influenced grain yield at only two sites (14GS27 and 14NO36) (Table 2 and Figure 3), with differences only present between the split N and the all at 0 WAS treatments.

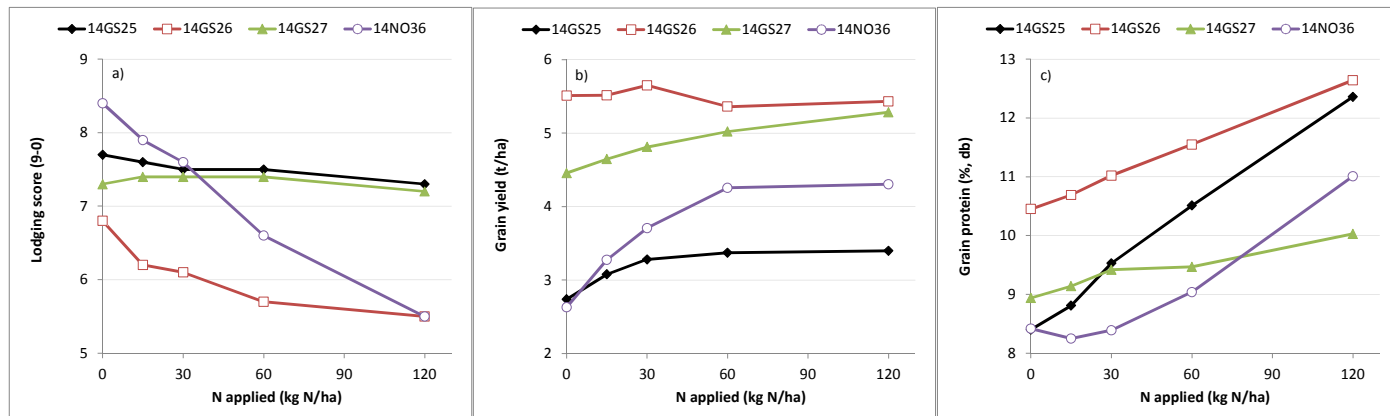


Figure 1. Response to N rate at each site for a) lodging [LSD ($p=0.05$): 14GS25 = 0.3, 14GS26 = 0.6, 14GS27 = 0.2 and 14NO36 = 0.3], b) grain yield [LSD ($p=0.05$): 14GS25 = 0.18, 14GS26 = 0.24, 14GS27 = 0.23 and 14NO36 = 0.15 t/ha] and c) grain protein [LSD ($p=0.05$): 14GS25 = 0.3, 14GS26 = 0.5, 14GS27 = 0.4 and 14NO36 = 0.2%].

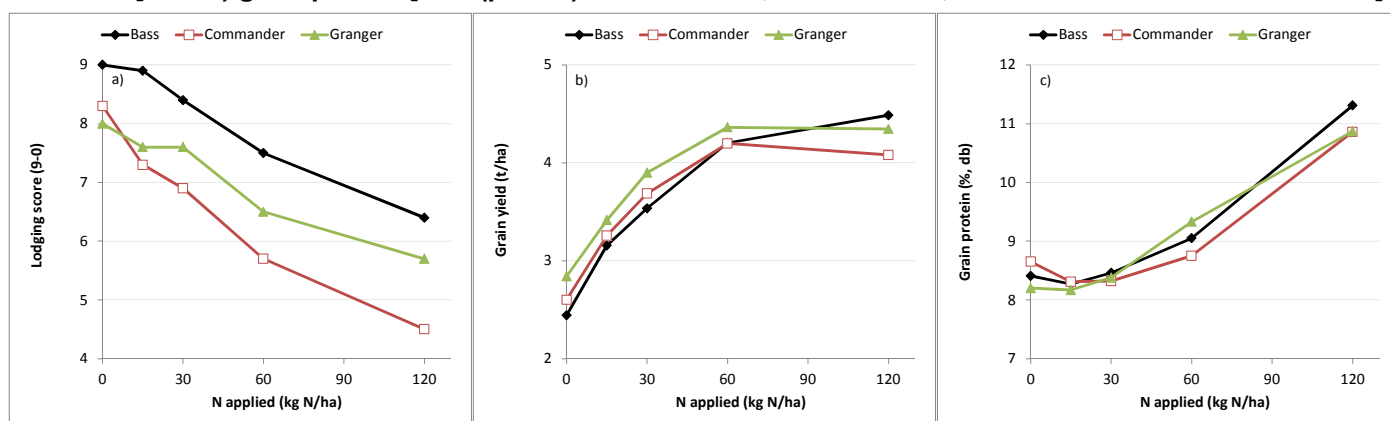


Figure 2. Varietal response to N rate at 14NO36 for a) lodging [LSD ($p=0.05$) = 0.4], b) grain yield [LSD ($p=0.05$) = 0.26 t/ha] and c) grain protein [LSD ($p=0.05$) = 0.4%].

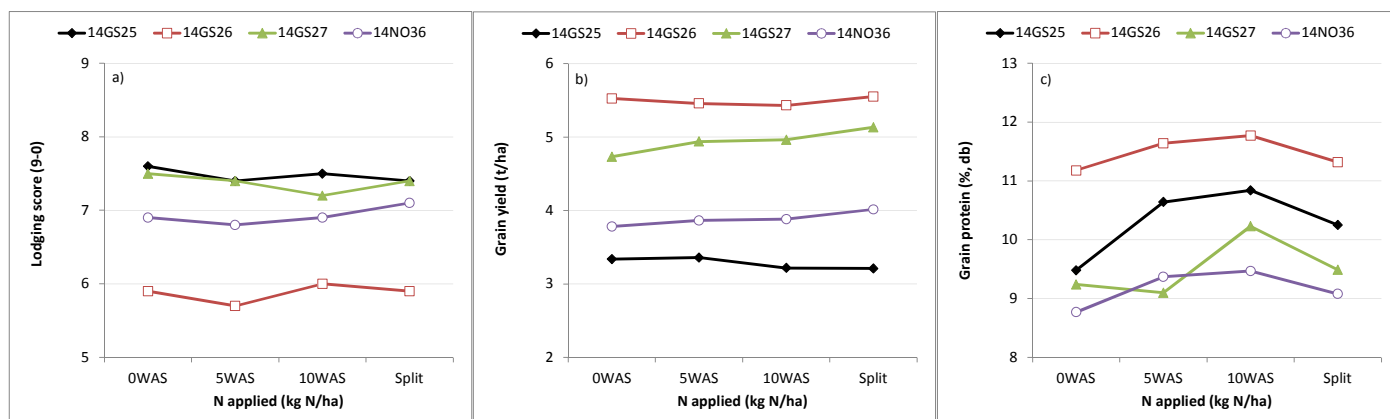


Figure 3. Response to N timing at each site for a) lodging [LSD ($p=0.05$): 14GS25 = 0.3, 14GS26 = 0.6, 14GS27 = 0.2 and 14NO36 = 0.3], b) grain yield [LSD ($p=0.05$): 14GS25 = 0.18, 14GS26 = 0.24, 14GS27 = 0.23 and 14NO36 = 0.15 t/ha] and c) grain protein [LSD ($p=0.05$): 14GS25 = 0.3, 14GS26 = 0.5, 14GS27 = 0.4 and 14NO36 = 0.2%].

Grain protein

Varieties differed in their GPC at only two sites (14GS25 and 14GS27) when averaged over N treatments (Tables 2 and 3). The trend of Commander having a lower GPC than Granger and Bass was present at three sites (although

only significant at 14GS27), but not at 14GS25. The overall difference in GPC between Bass and Commander was less than 0.3%, lower than the 1% difference observed in variety trials by Paynter and van Burgel (2014). When differences in their grain yield were accounted for there were no significant differences in the GPC of Commander, Granger and Bass (Figure 4).

There was a large GPC response to N rate at all sites (Figures 1 and 5). Varieties only differed in their response at 14NO36, with Bass more responsive to N than Commander and Granger (Table 2 and Figure 2).

N timing had a large influence on GPC at all sites (Figures 3 and 5). Delaying a single application of N from 0 to 5 or to 10 WAS resulted in increased GPC (Figure 3). Splitting N evenly did not return the same GPC as a single application at 5 or 10 WAS, but gave a higher GPC than putting on all the N at 0 WAS. The impact of N timing was less than the impact of N rate (Figures 1, 3 and 5). There was no variety x N timing interaction on GPC but there was an N timing x N rate interaction at all the sites sown into canola stubble (Table 2 and Figure 5). The GPC response to applied N was larger if applied at 10 WAS than at 0 WAS or if split. The GPC response to applying at N at 5 WAS was similar to applying it all at 10 WAS at both 14GS25 and 14NO36, but less effective at 14GS26.

Across varieties Malt1 grain protein receival specifications (9.5–12.5%) were achieved at 14GS25 with 60 and 120 N at 0 WAS; 30 and 60 N at 5 and 10 WAS or by split applications of 60 and 120 N (Figure 5). At 14GS26, Malt1 protein specifications were achieved with all N treatments except 120 N at 5 and 10 WAS (data not shown). For 14GS27 Malt1 protein specifications were only achieved with 30, 60 or 120 N at 10 WAS or a split application of 120 N. For 14NO36 Malt1 protein specifications were only achieved with 120 N at 0, 5 or 10 WAS or as a split application. Application of 0 N resulted in a GPC only suitable for delivery as feed at the three sites sown onto canola stubble (14GS25, 14GS27 and 14NO36) whereas the 0 N treatment was suitable for Malt1 delivery on the lupin stubble (14GS26). High protein (GPC > 12.8%) was only achieved by applying 120 N at 5 or 10 WAS at 14GS25 and 14GS26. Trial 14GS26 had the highest success rate for achieving malt (either Malt1 or Malt2) whereas 14NO36 had the lowest success rate.

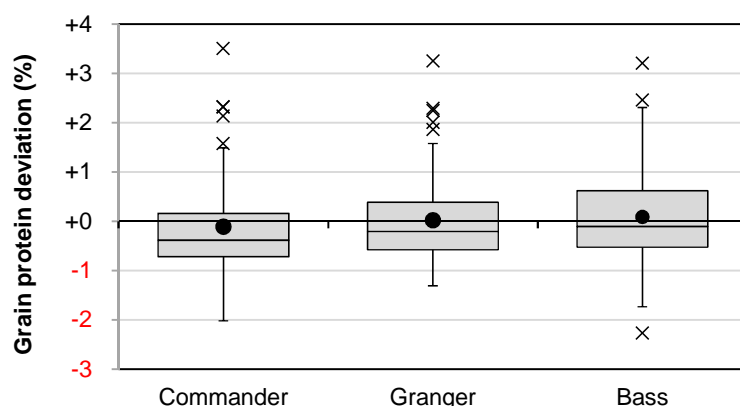


Figure 4. Boxplot of grain protein deviation (GPD) comparing three cultivars over all 17 N treatments across the four sites. Solid dots represent average GPD for each cultivar. Crosses highlight outliers.

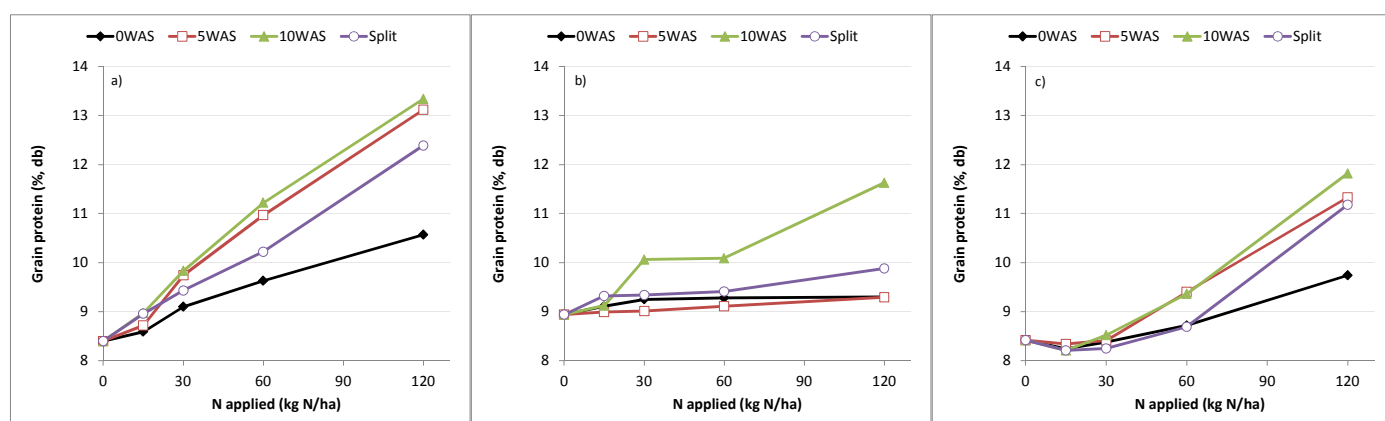


Figure 5. Grain protein response to N rate and N timing at three sites sown into canola stubble a) 14GS25 [LSD ($p=0.05$) = 0.4%], b) 14GS27 [LSD ($p=0.05$) = 0.5%] and c) 14NO36 [LSD ($p=0.05$) = 0.3%].

Conclusions

Barley growers in Western Australia are seeking to increase their grain yield without compromising their ability to meet malt barley receival specifications. This study compared how the lodging, grain yield and grain protein concentration (GPC) of three new malt barley varieties (Bass, Commander and Granger) responded to different N rates (0, 15, 30, 60 and 120 kg N/ha) and N timings (either 0 WAS, 5 WAS, 10 WAS or evenly split over those three dates).

Based on the premise that Bass, Commander and Granger genetically differ in their GPC when differences in their grain yield are accounted for (Paynter and van Burgel 2014), this study assessed whether or not different N management (N rate and N timing) strategies were required. Unfortunately no differences in GPC were found between Bass, Commander and Granger when differences in their grain yield were accounted for (Figure 4).

At these high yielding sites (site yields > 3 t/ha), no varietal interactions with N timing were observed and only one site showed a variety x N rate interaction for grain yield and GPC (Table 2). This suggests that different N management strategies are not required for Bass, Commander and Granger to maximise their grain yield and optimise their GPC.

What the study did demonstrate is that N rate and N timing were both important for managing GPC, whereas N rate was more important than N timing in driving increased grain yield (Table 2, Figures 1, 2, 3 and 5). The impact of N timing on GPC was less than the impact of N rate. Paynter (2005) and Hills and Paynter (2008) similarly observed that N rate was a primary determinant of GPC in barley (along with site). They also observed that the impact of variety and split applications were secondary.

Hills and Paynter (2008) also suggested that while the rate applied is more important than when it is applied, when it is applied is still an important component of getting the rate right. Such an influence of timing was observed at the three sites sown into canola stubble. At those sites applying all the N at 10 WAS produced grain with 1% more protein than when applied at 0 WAS and 0.5% more protein than when applied at 5 WAS with no difference in grain yield (Figure 3). The 10 WAS application also improved the probability of meeting Malt1 grain protein specifications. Splitting the N, however, increased the grain yield by about 0.1 t/ha compared to all the N at 10 WAS, but with 0.6% lower grain protein. Splitting the N also added nearly 0.2 t/ha compared to all the N at 0 WAS, but with 0.4% more protein.

Rotation was also important with the highest probability of achieving the Malt1 protein specification of 9.5 – 12.5% achieved by sowing barley into lupin stubble compared to the three trials sown into canola stubble. Bass and Granger were more suitable than Commander for sowing into a lupin stubble as Commander had severe lodging even with 0 N applied (data not shown). Bass and Granger still lodged but their degree of lodging was significantly less than in Commander.

Whilst measured but not reported in this study, differences in the plumpness of each variety will impact on how much N can be applied and what rotations a variety can be sown into. Plump grained varieties are less susceptible to high screenings as soil or fertiliser N supply increases (Paynter 2005, Hills and Paynter 2008, Paynter *et al* 2013).

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Key words

Barley, N rate, N timing, grain yield, grain protein concentration

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