National barley agronomy trial series (2012-2014) – Western Australian observations on the interaction between variety, nitrogen and seed rate

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Key messages

- The relative performance of varieties was not constant; they changed as the environment changed and in response to management (nitrogen (N) and seed rate).
- Knowledge of how a variety responded to increasing N was not helpful in understanding how the same variety responded to increasing seed rate.
- The optimum plant population for grain yield in this study decreased with increasing N from 171 to 136 plants/m^2 and averaged 160 ± 11 plants/m^2, which is in line with (although slightly above) the suggested target density for barley in Western Australia of 120 to 150 plants/m^2.
- The treatment that maximised the return ($/ha) from growing Bass and La Trobe was different to that of the established and nationally grown malt varieties Buloke and Commander, whereas Granger was the same.

Aims

There has been a rapid release and uptake of Barley Australia (barleyaustralia.com.au) accredited malting barley varieties in the last five years. Each newly released malt variety has a different phenotype, potentially resulting in differing responses to management inputs. In this study we looked at the influence of nitrogen (N) fertiliser at different seed rates on height, lodging, grain yield and grain quality parameters in a range of the new 'malt' barley varieties. The aim of the study was to assess varieties for their responsiveness to management and determine if a different management practice might be required to maximise productivity when growing each variety.

Method

This study was a collaboration between the western (DAW00224) and southern (DAN00173) GRDC funded barley agronomy projects over a three year period (2012-2014). In each year a core set of eight 'malt' varieties were evaluated at seven locations (three in WA, two in NSW, one in Vic and one in SA). The eight varieties sown were evaluated for their response to three rates of applied N (0, 30 and 90 kg N/ha) at three different seed rates (75, 150 and 300 plants/m^2) over three replicates. Trials were designed with a block structure of (rep+colrep)/(variety . N applied)/seed rate and a treatment structure of variety x N applied x seed rate. Only the Western Australian component is reported in this paper, with the whole national series reported together in Paynter *et al*. (2015a).

The malting varieties Bass, Buloke, Commander, Granger, La Trobe and Wimmera were sown in all nine trials (sites). Trials were established each year at Walebing, Katanning area and Gibson in each of 2012, 2013 and 2014 (Table 1). Buloke and Commander were the control varieties given their adoption in all the major malt growing areas of Australia. Compass (under malt evaluation), Flinders (now an accredited malt variety) and Skipper (withdrawn from accreditation) were also sown, but not in all trials, with data for those three varieties not presented in this paper.

Trials were established into canola stubble with small plot seeding equipment and harvested with small plot research equipment. N (as urea) was topdressed by hand after seeding. The seed rate (kg/ha) to establish the target densities of 75, 150 or 300 plants/m^2 varied for each variety and year and was adjusted based on their kernel weight and germination per cent. Results are graphed against the measured establishment (determined 2 to 4 weeks after seeding) rather than against the target densities. Measurements included plant establishment (plants/m^2), plant height (cm, base of ear), lodging score (9-0) close to harvest, grain yield (t/ha), kernel weight (mg, db), hectolitre weight (kg/hL), screenings (% < 2.5 mm), grain protein concentration (%, db) and grain brightness (Minolta 'L*').

A MET analysis was conducted on the combined nine site dataset for each of the core measurements. Spatial analysis was undertaken with an autoregressive correlation matrix using ASReml3 for R (Gilmour *et al.* 2009, R Core Team 2015). Screenings and grain protein data was transformed in the spatial analysis. Performance of each variety relative to the performance of Buloke was assessed within GenStat (VSN International 2013) using a linear function model. Grain yield and screenings data was log transformed for the comparative analysis. Grain protein deviation based on the relationship between grain yield and grain protein concentration was calculated with GenStat as per Paynter and van Burgel (2014). The optimum plant population for grain yield was calculated for each N rate at each site as per Paynter (2016) with the point of inflection at 1.5 kg/ha of grain for each extra established plant/m^2.

Results

Site and variety

Growing season rainfall (May-Oct) was greater than 220 mm at each site (Table 1). The site mean grain yield ranged from 2.87 t/ha (Walebing 2014) to 5.25 t/ha (Kendenup 2013) with an average yield of 4.19 ± 0.26 t/ha. Grain quality was generally within the GIWA Barley Malt 1 limits (hectolitre weight ≥64 kg/hL, screenings ≤20%, grain protein between 9.5% to 12.5% and grain brightness ≥56 'L*') with a few exceptions. High screenings (site average >35%) was present at Katanning 2012 and low grain brightness (site average <55 'L*'') observed at Kendenup 2013.

Table 1. Trials details for the nine barley agronomy variety by N applied by seed rate trials.

Site	Location	Sown (date)	May-Oct rainfall (mm)	Site mean yield (t/ha)	pH_{Ca} (0-10cm)	Soil type
12WH26	Walebing	18-Jun-12	224	4.23	5.6	brown shallow sandy duplex
12GS32	Katanning	28-Jun-12	274	3.44	4.6	ironstone gravel
12ED19	Gibson	23-May-12	300	4.96	4.4	grey duplex sandy gravel
13WH17	Walebing	15-May-13	230	3.98	5.4	brown shallow sandy duplex
13GS35	Kendenup	05-Jun-13	362	5.25	4.8	brown duplex sandy gravel
13ED23	Gibson	15-May-13	337	4.84	5.8	grey deep sandy duplex
14WH18	Walebing	14-May-14	254	2.87	6.3	grey shallow loamy duplex
14GS24	Kojonup-W	30-May-14	372	3.76	5.2	reddish brown deep sandy duplex
14ED28	Gibson	02-Jun-14	433	4.41	5.6	pale sandy earth

Table 2. Varietal differences in plant height, lodging, grain yield and grain quality averaged across sites. Significance: *** = p<0.001, ** = p<0.01, * = p<0.05 and n.s. = not significant.

Trait Variety	Plant height (cm)	Lodging (9-0)	Grain yield (t/ha)	Kernel weight (mg, db)	Hectolitre weight (kg/hL)	Screenings (%<2.5mm)	Grain protein (%, db)	Grain brightness ('L*')
Bass	58	8.0	4.10	43.0	71.6	6	11.1	58.3
Buloke	72	6.8	4.06	43.7	69.6	14	10.6	58.3
Commander	65	7.3	4.15	40.4	68.8	11	10.3	58.9
Granger	66	7.9	4.28	43.5	70.5	7	10.6	57.3
La Trobe	60	7.7	4.42	40.4	70.9	10	10.4	57.7
Wimmera	56	7.9	4.13	40.1	68.9	10	10.7	59.1
Significance	***	***	***	***	***	***	***	***
LSD (p=0.05)	1	0.2	0.06	0.4	0.2	1	0.0	0.1

Table 3. Analysis of variance for main effects (site, variety, N applied and seed rate) and their interactions. Significance: *** = p<0.001, ** = p<0.01, * = p<0.05 and n.s. = not significant.

Trait Variety	Plant height (cm)	Lodging (9-0)	Grain yield (t/ha)	Kernel weight (mg, db)	Hectolitre weight (kg/hL)	Screenings (%<2.5mm)	Grain protein (%, db)	Grain brightness ('L*')
Site (S)	***	***	***	***	***	***	***	***
Variety (V)	***	***	***	***	***	***	***	***
N applied (N)	***	***	***	***	***	***	***	***
Seed rate (SR)	***	***	***	***	***	***	***	***
S x V	***	***	***	***	***	***	***	***
S x N	***	***	***	***	***	***	***	***
V x N	***	n.s.	***	n.s.	***	***	***	***
S x SR	***	*	***	***	***	***	***	***
V x SR	***	n.s.	***	***	***	***	***	***
N x SR	n.s.	n.s.	***	*	n.s.	***	***	**
S x V x N	***	***	***	***	***	***	***	***
S x V x SR	***	*	***	***	***	***	*	***
S x N x SR	*	n.s.	***	***	**	***	n.s.	**
V x N x SR	n.s.	n.s.	*	**	n.s.	n.s.	n.s.	n.s.
S x V x N x SR	n.s.	*	n.s.	*	**	***	n.s.	n.s.

With nil N applied, grain protein concentrations were below 9% at three sites (Kendenup 2013, Walebing 2013 and 2014, and Kojonup-W 2014) and above 12.8% at one site (Katanning 2012). Low (<9%) or high (>12.8%) grain protein was the main cause of downgrading to feed across sites with or without N application.

Varieties differed in their plant height, lodging scores, grain yield and grain quality (Table 2). La Trobe was the highest yielding variety, out-yielding Buloke by 0.36 t/ha when averaged across sites and all varieties at levels of grain yield above 3 t/ha (Table 2 and Figure 1). Varieties also differed in their physical grain characteristics (Table 2 and Figure 2). Bass, Buloke and Granger had a higher average kernel weight than Commander, La Trobe and Wimmera. Bass had the highest average hectolitre weight but at low hectolitre weights La Trobe was higher than Bass. Bass and Granger had the plumpest grain, with Bass slightly plumper than Granger at sites with screenings below 30%.

Wimmera had the brightest grain, especially at sites with a brightness level below 59 ‘L*”. When the influence of grain yield was removed, Bass and Commander differed from the other four varieties in their grain protein concentration (Figure 2). At a given yield and management input, the grain protein concentration in Bass and Commander differed by up to 1%. The grain protein deviation of Bass and Commander is consistent with the analysis of barley NVT trials in South Australia (Porker and Wheeler 2013) and in Western Australia (Paynter and van Burgel 2014). The ranking of Buloke, Granger, La Trobe and Wimmera varied across the rates of N applied. When all the data was combined, the grain protein deviation of those four varieties did not deviate from zero (data not shown), but did in some cases at the different rates of applied N. The analysis suggests that Buloke and La Trobe are low protein varieties at high N and Wimmera a high protein variety at high N. In the analysis of Paynter and van Burgel (2014) Buloke was ranked as having a slightly lower grain protein concentration for its yield, Wimmera slightly higher and La Trobe was considered normal. These differences in grain quality influenced the success of each variety in meeting the GIWA Barley Malt 1 and Malt 2 standards as N and/or seed rate was increased.

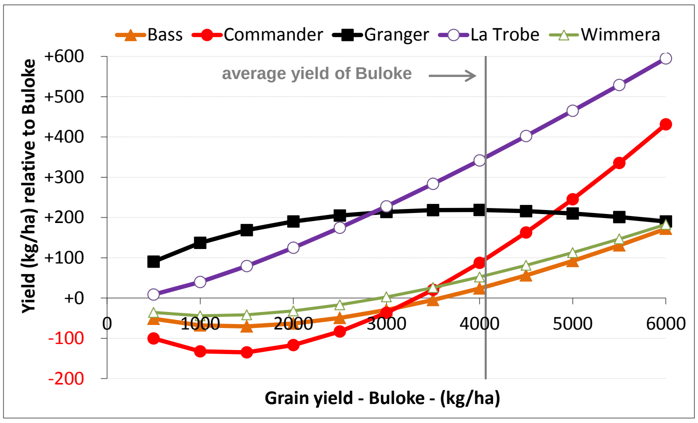

Figure 1. Relative grain yield (kg/ha) of Bass (r^2 = 0.85), Commander (r^2 = 0.82), Granger (r^2 = 0.79), La Trobe (r^2 = 0.69) and Wimmera (r^2 = 0.70) at different grain yields achieved by Buloke.

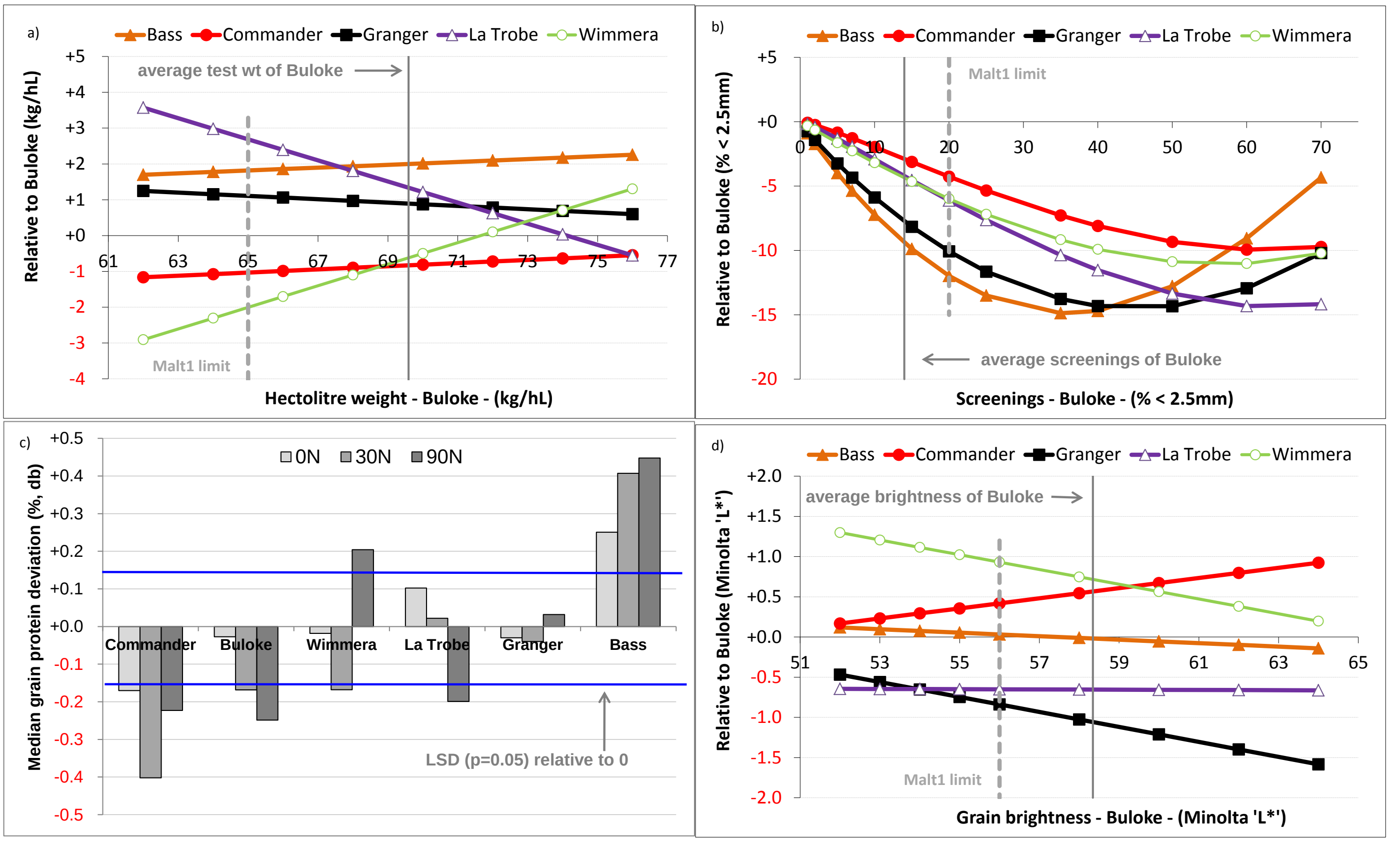

Figure 2. a) Relative hectolitre weight of Bass (r^2 = 0.91), Commander (r^2 = 0.80), Granger (r^2 = 0.90), La Trobe (r^2 = 0.79) and Wimmera (r^2 = 0.65) at different hectolitre weights achieved by Buloke; b) relative screenings of Bass (r^2 = 0.83), Commander (r^2 = 0.85), Granger (r^2 = 0.80), La Trobe (r^2 = 0.60) and Wimmera (r^2 = 0.80) at different screenings achieved by Buloke, c) median grain protein deviation of Bass, Commander, Granger, La Trobe and Wimmera when the influence of differences in their grain yield is removed; and d) relative grain brightness of Bass (r^2 = 0.95), Commander (r^2 = 0.90), Granger (r^2 = 0.90), La Trobe (r^2 = 0.84) and Wimmera (r^2 = 0.91) at different brightness levels achieved by Buloke.

Nitrogen and seed rate

N and seed rate both influenced yield and quality (Table 2). Across sites, the absolute effect (and direction of change) of increasing N from 0 to 90 kg N/ha or increasing the seed rate from 75 to 300 plants/m^2 was similar for grain yield (+0.29 vs +0.38 t/ha), kernel weight (-2.6 vs -2.9 mg), hectolitre weight (-0.7 vs -0.7 kg/hL) and grain brightness (+0.3 vs +0.1 'L*'). N had a much larger effect on plant height (+7 vs +3 cm), lodging (-0.5 vs +0.1), screenings (+8 vs +3%) and grain protein (+2.5% vs -0.1%) than seed rate. N increased rather than decreased lodging risk and grain protein relative to seed rate.

Whilst there was a similar absolute change due to increasing N and increasing seed rate, the shapes of the yield response curves for N and seed rate however differed. Across sites grain yield increased by 8% with N application, plateauing at 30 N. For seed rate, grain continued to increase with increasing seed rate. There was a 7% increase in grain yield as seed rate increased from 75 to 150 plants/m^2 and a further 3% increase between 150 and 300 plants/m^2.

The optimum plant population for grain yield ranged between 71 plants/m^2 (Kojonup 2014, 30 N) to 280 plants/m^2 (Kojonup-W 2013, 0 N and 30 N) with an average across sites and for all rates of N of 160 ± 11 plants/m^2. The optimum plant population for grain yield was not correlated with the site mean yield (data not shown), but did decrease with increasing N. The optimum plant population for grain yield with 0 N was 171 ± 20 plants/m^2; with 30 N 154 ± 20 plants/m^2 and 136 ± 16 plants/m^2 with 90 N.

Table 4. Responsiveness of varieties to increasing N applied or increasing seed rate when averaged across sites for height, lodging, grain yield and five grain quality traits.

Treatment	N applied		Seeding rate	
Trait and change	Smallest change	Largest change	Smallest change	Largest change
Plant height	Buloke, Granger, La Trobe	Bass	Granger, Wimmera	Bass, Buloke
Lodging	-	-	-	-
Grain yield	Granger	La Trobe	Buloke	-
Kernel weight	-	-	-	Granger
Hectolitre weight	La Trobe	Bass, Buloke, Wimmera	Bass, Commander	Granger, Wimmera
Screenings	Granger, Wimmera	Buloke	Bass, Commander	Buloke, Granger, Wimmera
Grain protein	La Trobe	Bass, Wimmera	Bass, Buloke, Commander	Granger
Grain brightness	Bass, Granger	Commander, La Trobe	Bass	-

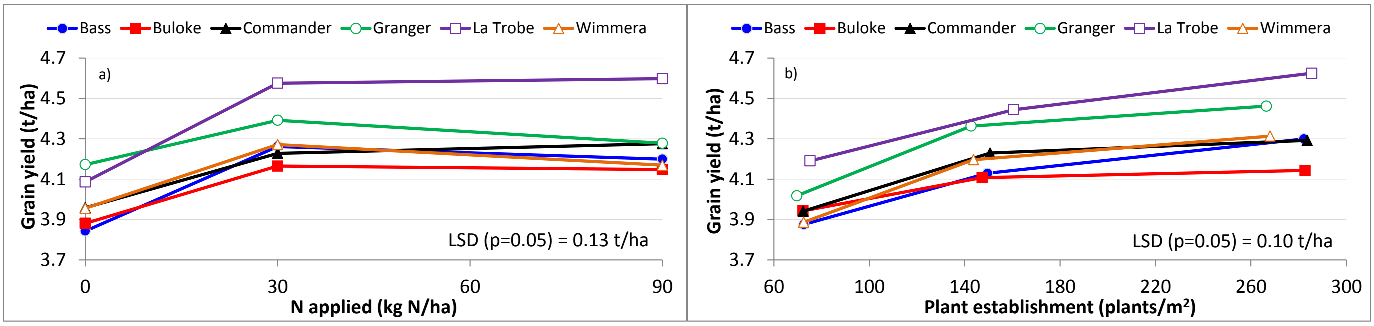

Figure 3. Response of six barley varieties to a) increasing N applied or b) increasing seed rate (plotted against established plant number) when averaged across sites for grain yield.

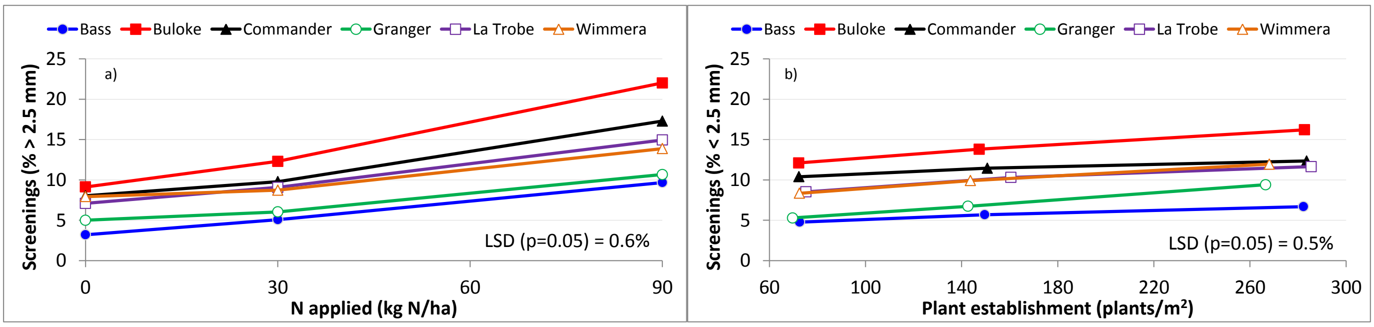

Figure 4. Response of six barley varieties to a) increasing N applied or b) increasing seed rate (plotted against established plant number) when averaged across sites for screenings.

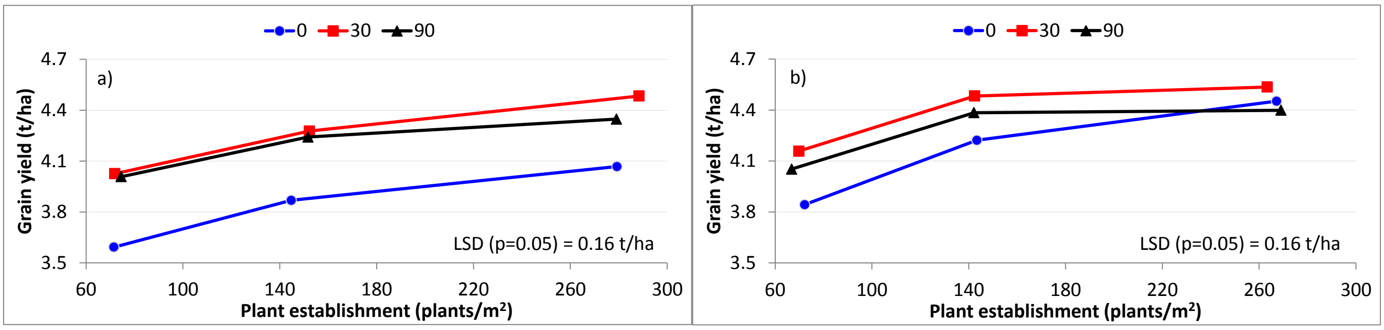

Figure 5. Difference in the grain yield response of two varieties a) Bass and b) Granger to increasing N applied at different seed rates averaged across sites.

Table 5. Average grain yield, per cent of samples meeting GIWA Barley receival standards (Malt 1 or Malt 2) and return per ha (yield by price minus costs) for each N applied and seed rate treatment averaged across sites. Maximum values highlighted in bold.

		Grain yield (t/ha)			% samples meeting GIWA Barley Malt 1 or 2 standards			Return ($/ha)		
Variety	Treatment	75 plants/m^2	150 plants/m^2	300 plants/m^2	75 plants/m^2	150 plants/m^2	300 plants/m^2	75 plants/m^2	150 plants/m^2	300 plants/m^2
Bass	0 N	3.59	3.87	4.07	33%	22%	22%	$532	$540	$546
	30 N	4.03	4.28	**4.48**	**67%**	56%	**67%**	$585	$613	**$622**
	90 N	4.01	4.24	4.35	44%	44%	33%	$487	$515	$488
Buloke	0 N	3.74	3.92	3.98	33%	22%	44%	$551	$565	$529
	30 N	4.00	4.24	**4.25**	44%	56%	56%	$571	**$604**	$567
	90 N	4.09	4.16	4.20	**67%**	22%	33%	$523	$482	$450
Commander	0 N	3.75	3.99	4.13	44%	56%	44%	$551	$598	$580
	30 N	3.99	4.32	4.37	56%	56%	56%	$566	**$617**	$594
	90 N	4.08	4.37	**4.38**	56%	**78%**	67%	$497	$569	$521
Granger	0 N	3.84	4.22	4.45	33%	22%	44%	$557	$598	$627
	30 N	4.16	4.48	**4.54**	**56%**	**56%**	**56%**	$598	**$638**	$614
	90 N	4.05	4.38	4.40	44%	33%	33%	$486	$530	$488
La Trobe	0 N	3.80	4.14	4.32	44%	33%	33%	$557	$615	$607
	30 N	4.37	4.52	**4.83**	56%	**67%**	**67%**	$644	$660	**$680**
	90 N	4.40	4.67	4.73	56%	**67%**	**67%**	$577	$607	$577
Wimmera	0 N	3.63	4.04	4.20	44%	44%	**56%**	$546	$594	$586
	30 N	4.05	4.33	**4.44**	44%	44%	44%	$578	**$618**	$597
	90 N	3.98	4.22	4.31	33%	22%	33%	$468	$491	$481

Varietal interactions with nitrogen or seed rate

Varieties responded differently to increasing N applied (except lodging and kernel weight) and to increasing seed rate (except lodging) (Tables 3 and 4, Figures 2, 3 and 4). This response was also influenced by site (Table 3). The response of a variety to N was not a good indicator of how the same variety responded to increasing seed rate (Table 4). For example La Trobe was the most yield responsive variety to increasing N but no different to other varieties in its response to increasing seed rate (except Buloke). The grain quality of Granger was more responsive to increasing seed rate than other varieties, but its grain quality was not the most responsive to increasing N applied (Table 4).

Varietal interactions with nitrogen and seed rate

N and seed rate interacted to influence grain yield and grain quality, except height, lodging and hectolitre weight (Table 3). Height and hectolitre weight responses to seed rate and N, however, were apparent at some sites but not all sites. As seed rate increased, barley became less grain yield responsive to increasing N with a higher small grain risk and therefore associated with lower hectolitre weight, higher screenings and slightly brighter grain (data not shown). There was no interaction for height or lodging. The influence of seed rate and N varied with site, except for lodging and grain protein concentration.

Interactions between seed rate and N applied were only modified by variety for grain yield (eg. Bass and Granger, Figure 5) and kernel weight, although their interaction on lodging, kernel weight, hectolitre weight and screenings was present at some sites but not all sites (Table 3). The influence of seed rate and N on varietal responses on grain yield was not modified by site.

At 300 plants/m^2, Granger and Wimmera achieved similar grain yields regardless of the level of N applied (Table 5 and illustrated for Granger in Figure 5). Whereas at 75 plants/m^2 their grain yield differed with N applied. In the other four varieties, the yield of the 0 N plots were always lower than the yield of the 30 N and 90 N plots at each seed rate.

For Bass and Commander there was almost no change in retention as seed rate increased for both the 0 N and 30 N treatments, but retention decreased slightly as seed rate increased at 90 N (data not shown). For the other four varieties the decrease in retention with increasing seed rate was present at each rate of N applied and became larger with each increase in N applied.

Maximising yield and quality

The management package that maximised grain yield was generally not the same as that which had the highest proportion of the sites meeting the GIWA Barley Malt 1 or Malt 2 receival limits for hectolitre weight, screenings, grain protein and grain brightness (Table 5). The strike rate for malt (either Malt 1 or Malt 2) ranged from as low as 22% (2 in 9 trials) to as high as 78% (7 in 9 trials). Commander and La Trobe had the highest per cent of samples meeting malt barley receival standards, whilst the other four varieties were similar.

In almost all varieties grain yield was maximised with 30 N and sowing a target density of 300 plants/m^2.

In both Bass and Granger, the 30 N treatments gave the highest strike rates as malt, whereas it was achieved with 0 N and a target density of 300 plants/m^2 in Wimmera. A higher production package suited La Trobe better with its strike rate highest at 30 or 90 N and 150 or 300 plants/m^2. In Buloke and Commander the highest strike rate as malt was achieved with 90 N and 75 plants/m^2 in Buloke and 150 plants/m^2 in Commander.

Economic analysis

An economic analysis calculating return (yield by price minus costs) was done for each variety, treatment (N and seed rate combination) and site, using the assumptions in Table 6 and the current GIWA Barley receival standards for Western Australia. The average return ($/ha) across all nine sites is presented in Table 5. It should be noted that these trials were not designed to determine the optimum N and seed rate package for each variety. The treatments chosen were designed to facilitate the discrimination of varietal performance rather than be economic rates of N application or farmer used seed rates. Operating costs do not take into account differences in disease control that may be required and the analysis assumes all varieties can be delivered to the same bin.

Table 6. Assumptions used in the economic analysis of the nine barley agronomy trials.

	Indicative cash price ($/t)			EPR ($/t)	1000 seed weight (g)	Seed rate (kg/ha) to achieve		
Variety	Malt 1	Malt 2	Feed			75 plants/m^2	150 plants/m^2	300 plants/m^2
Bass	$265	$240	$230	$3.50	45	41	86	197
Buloke	$260	$240	$230	$2.00	45	41	86	197
Commander	$260	$240	$230	$3.80	42	38	80	184
Granger	$260	$240	$230	$2.95	45	41	86	197
La Trobe	$260	$240	$230	$4.00	42	38	80	184
Wimmera	$260	$240	$230	$3.00	42	38	80	184
Establishment per cent						85%	80%	70%

Barley receival + BAMA	$12.50	$/t	
Freight: farm to port	$22.50	$/t	farm to bin + bin to natural port
Seed cost	$350	$/t	
Seed dressing cost	$61	$/t	
Germination per cent	98	%	
Operating costs	$180	$/ha	fuel, P fertiliser, weed control, foliar fungicides
Urea cost	$540	$/t	
Urea spreading cost	$10	$/ha	
R&D levy	1.02%	farm gate value	

Note: cash price for Granger and Wimmera assumed to be similar to Buloke as no cash price has been posted in Western Australia.

The treatment that maximised returns per hectare (based on assumptions in Table 6 and against the current GIWA Barley receival standards) was generally not the same as that which had the highest proportion of the sites meeting the GIWA Barley Malt 1 or Malt 2 receival standards or the highest grain yield (Table 5).

For the treatments used, the return of Bass and La Trobe was maximised with 30 N and sowing at a target density of 300 plants/m^2, with La Trobe having a higher return than Bass ($680 vs & $622/ha). This was the same treatment that maximised their grain yield and one of the treatments that maximised their receival as malt, but different to the maximising treatment for Buloke, Commander, Granger and Wimmera.

The maximum return of Buloke was lower than Bass, Commander, Granger, La Trobe and Wimmera (Table 5). The maximum return of Commander and Wimmera was similar to Bass with Granger higher. The maximum return of Buloke, Commander, Granger and Wimmera was maximised with 30 N and sowing a target density of 150 plants/m^2. This was not the same treatment that maximised grain yield or maximised receival as malt (except Granger). With the same agronomy (30 N and 150 plants/m^2), however, the return from Bass was similar to that of Commander and Wimmera, higher than Buloke (-$15/ha) and lower than Granger (+$19/ha) and La Trobe (+$61/ha). Granger made more $/ha than Bass because of its higher yield and similar % received as malt, despite a $5/ha difference in their indicative Malt1 cash price.

Conclusion

Bass, Granger, La Trobe and Wimmera differed in how they responded to management relative to the established varieties Buloke and Commander, with the response of each variety to management (N applied and/or seed rate) trait dependent and management related (Tables 3, 4 and 5). Varietal responsiveness varied with each trait and differed by management input. Maximising the productivity of each variety is therefore a balancing act. An ideal variety has a high hectolitre weight, low screenings with low to moderate grain protein concentration, a high grain brightness, doesn't hay off at high N and is not very responsive to seed rate. None of the varieties evaluated displayed all those characteristics. Each variety however can be successful if you manage its weaknesses for your environment.

So although we were able to establish that varieties did differ in their response to the management inputs N and seed rate for some traits, varietal differences were generally small (ie. grain brightness for both N and seed rate), but some were however large (screenings for N but not seed rate) (Tables 4 and 5, Figures 3, 4 and 5). Although the response to increasing seed rate was influenced by the amount of N applied, varieties only responded consistently differently for grain yield and kernel weight.

In this study, low or high grain protein was the most common reason for downgrading to feed barley (data not shown). More treatments around 30 N would have resulted in fewer samples achieving the grain protein receival standards and would have influenced the economic analysis undertaken. The differences in hectolitre weight, screenings and grain brightness did not result in large differences between the varieties in their ability to meet GIWA Barley Malt 1 or Malt 2 receival standards (Table 5, Figure 2). Bass was the plumpest of the varieties tested with a high hectolitre weight, but was also a higher risk of not meeting grain protein standards in both low and high N situations. Granger was not very responsive to increasing N, but its grain quality was more sensitive to increasing seed rate than the other varieties. Granger had a slightly higher risk of grain brightness downgrade than the other varieties tested. Whereas La Trobe was very responsive to both increasing N and increasing seed rate, it was able to maintain a good grain quality, the exception being at low N supply.

Growers need to focus on maximising returns (yield by quality) rather than focusing on maximising yield when growing malt barley. Maximum yield and maximum receival quality rarely occurred under the same management (Table 5). Similarly maximum return and maximum yield or maximum quality rarely occurred under the same management.

In this study the treatment that maximised the returns of Bass and La Trobe was different to that that maximised the return from Buloke, Commander, Granger and Wimmera (Table 5). The highest profit (based on economic assumptions used) for Bass and La Trobe was achieved at 30 N and 300 plants/m^2 and for Granger at 30 N and 150 plants/m^2. La Trobe was able to more consistently meet malt barley receival standards than Bass and Granger with a higher yield potential and a higher profit. These management observations for Bass, Granger and La Trobe are similar to that observed when this data was combined with similar trials in eastern Australia in a larger analysis (Paynter *et al*. 2015*a*) and to the study of Paynter *et al*. (2016a).

Whilst Buloke rather than Scope CL was used in this study, it should be expected that Scope CL will react similarly to Buloke to applied N and seed rate. This statement is based on the similarity of their performance in National Variety Trials and barley agronomy trials in Western Australia (ie. Paynter *et al*. 2015b).

In this study the optimum plant population for grain yield averaged over sites and rates of N was 160 ± 11 plants/m^2. Like Paynter *et al*. (2016a and 2016b), the optimum plant population for grain yield was not influenced by site mean yield, but in this study it was influenced by N. The optimum plant population decreased with increasing N supply, being 171 ± 20 plants/m^2 with 0 N and 136 ± 16 plants/m^2 with 90 N. The optimum plant populations observed in this study are in line with the current target establishment densities of 120 to 150 plants/m^2 for barley grown in Western Australia.

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Key words

Barley, nitrogen, seed rate, grain yield, grain quality, return, profit, optimum plant population

Acknowledgments

The authors acknowledge the technical support in DAW00224 of Sue Cartledge, Rod Bowey, Georgia Oliver and Rachel Brunt and the DAFWA Technical Support Units at Wongan Hills, Katanning and Esperance. We also acknowledge the support of the farmers (Kristin Lefroy, Walebing; Ben Webb, Kojonup; and Bradley Woods, Kendenup) who provided land for these research trials. Economic analysis costs and prices were supplied by David Cameron, Farmanco and Drew Robertson, CBH. This research is supported by the Department of Agriculture and Food Western Australia with co-funding from the Grains Research and Development Corporation. Rick Graham, New South Wales Department of Primary Industry, provided feedback on a draft of this paper.

GRDC Project Number: DAW00224