Management effects on barley varieties – row spacing, nitrogen and weed competition

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Take home messages

- *Variety choice was the management decision with the highest impact on grain yield and gross income compared to other management considerations.*
- *Hindmarsh was the highest ranking variety for yield but Commander was the highest ranking for gross income (this will change if Hindmarsh receives malt accreditation in 2011).*
- *Row spacing effects on yield were negligible in a year with a dry spring, however significant effects on plant density, shoot density and brome grass populations were observed.*
- *Variety differences in response to weed management were difficult to detect but weed management in general was important to protect yield in the case of ryegrass at St Arnaud and prevent seed set in the case of brome grass at Woomelang.*
- *There is growing evidence that varieties respond differently to nitrogen management.*

Background

This is the third year of a large tri-state project jointly funded by GRDC and SAGIT investigating the response of barley varieties to various aspects of crop management, particularly aspects associated with no-till farming systems. This paper reports on 3 trials managed by BCG in 2009 with some reference to outcomes from previous years.

Aim

To evaluate the response of different barley varieties to various aspects of crop management. Variables examined include nitrogen (N) timing, weed management, weed competition and row spacing.

Method

Locations:	Woomelang and St Arnaud
Trials	3 (*Weed Competition North (*WCNth) and *Nitrogen* (N) at Woomelang, *Weed Competition South* (WCSth) at St Arnaud)
Replicates:	4 (split plot factorial designs)
Sowing date:	WCNth: 11 – 12 May; N: 19 May; WCSth: 29 May
Seeding density:	130 plants/m² (sowing rates adjusted for each variety)

Crop type:	Barley
Seeding equipment:	Knife point, press wheels, 15, 22.5, 30cm row spacing
Growing season rainfall	209mm at Woomelang; 231mm at St Arnaud
Soil type	Mallee sandy loam at Woomelang Grey vertisol at St Arnaud

Three trials were established into standing cereal stubbles and were sown with knife points and press wheels. There was moderate stubble cover at both sites. All trials received a knockdown herbicide prior to sowing. 2 trials were established at Woomelang.

The first trial WCNth was sown into dry soil on 11 – 12 May, and the second trial (N)) was sown on 30cm spacing into moisture 4cm below the soil surface on 19 May with1L/ha TriflurX applied pre-sowing with the knockdown herbicide. A weed competition trial (WCSth) was also established at St Arnaud into moist soil on 29 May. Treatments for the weed competition trials included row spacing, variety and weed management (Table1). Treatments for the N trial included N timing and variety (Table 1). All trials received 55kg/ha MAP at sowing. WCNth had 26kg/ha N applied as UAN at late tillering. WCSth did not require post-emergent N. Broadleaf weeds were controlled at each site. Aphids were controlled at the Woomelang site and barley scald and army worm were managed at the St Arnaud site.

The weed competition trials were designed to create 2 scenarios at each site. A 'plus weed' scenario and 'minus weed' scenario to examine the variety response to the effect of weed competition and row spacing. This was one area of research where little data had been collected in the earlier years of this project. At Woomelang the weed species of interest was brome grass while at St Arnaud it was annual ryegrass.

At Woomelang, grass weed population differences were achieved by spreading 10kg/ha brome grass seed before sowing for the '+Brome' treatments, and using a pre-emergent herbicide and not spreading brome for the '–Brome' treatments.

At St Arnaud, distribution of ryegrass throughout the trial site was such that header rows with high densities of ryegrass ran perpendicular to the plots and therefore each plot had one header row running through it (approximately 10% of plot area). The – Ryegrass treatments were created by using pre-emergent herbicide. The +Ryegrass treatments received no pre-emergent herbicide. Crop and weed measurements were mostly taken in the general plot area (ie non-header row areas) but some measurements were taken in the header rows as well. Due to the large ryegrass numbers in the header rows of some plots, early season ryegrass populations were estimated using a photo guided scoring system and then representative plots were counted to gain an estimate of ryegrass populations for each rating category. The scoring system used was 1 – approx 50 plants/m^2; 2 – approx 1000 plants/ m^2 ;5 – approx 2000 plants/m^2 and 10 – approx 3000 plants/m^2.

For each trial plant establishment, shoot density, weed presence, dry matter production, grain yield and quality parameters were measured.

Table 1. Matrix of treatments for the three sites.

Location	Woomelang		St Arnaud
Trial Name	**Nitrogen**	**WCNth**	**WCSth**
Row spacing		• 15cm • 22.5cm • 30cm	• 15cm • 22.5cm • 30cm
Weed management		• **+Brome:** Brome seed spread. No pre-emergent herbicide • **- Brome:** No Brome spread. TriflurX 1.5L/ha + Lexone 140g/ha	• **+Ryegrass:** No pre-emergent herbicide • **- Ryegrass:** Boxer Gold 2.5L/ha
Nitrogen timing	• Nil • Pre-sow 40kg/ha N (87kg/ha urea) • GS30 40kg/ha N (87kg/ha urea) 15 July		
Variety	• Buloke • Commander • Flagship • Fleet • Hindmarsh • Sloop Vic	• Buloke • Commander • Hindmarsh • Sloop Vic	• Buloke • Commander • Hindmarsh • Sloop Vic

TriflurX is Trifluralin 480g/L; Lexone i metribuzin 750g/L; Boxer Gold is 800g/L prosulfocarb (Group E) and 120g/L s-metolachlor.

Results

What was the effect of row spacing?

The effect of row spacing was examined in the weed competition trials at Woomelang and St Arnaud.

Weed populations are examined in detail in a latter section. In general brome populations at Woomelang, without pre-emergent herbicide, showed a strong trend toward higher numbers at the widest row spacing compared to the narrowest row spacing (in both early brome populations (P=0.06) and final brome heads/m^2 measured prior to harvest (P=0.08)). Differences in ryegrass populations at St Arnaud due to row spacing were not detectable either early in the season or at harvest.

Plant establishment was close to the target plant density at both sites for all row spacings (Table 2a). Plant density at 15cm row spacing was significantly higher than 22.5cm or 30cm spacing. However, when expressed on a lineal basis (per metre row), increased row spacing resulted in significantly more plants per row.

Table 2a. Effect of row spacing on plant density of barley at GS14. The means are calculated from all treatments for each spacing.

Row spacing	Plant density/m²		Plant density/m row	
	WCNth W'lang	WCSth StArn'd	WCNth W'lang	WCSth StArn'd
15cm	141	155	21	23
22.5cm	130	138	29	31
30cm	126	141	38	42
P Value	**0.002**	**0.001**	**<0.001**	**<0.001**
LSD (5%)	**6**	**6.5**	**1.6**	**1.4**

Table2b. Effect of row spacing on shoot and head density of barley. The means are calculated from all treatments for each spacing.

Row spacing	Shoot density/m²		Spike density/m²	
	WCNth W'lang	WCSth StArn'd	WCNth W'lang	WCSth StArn'd
15cm	560	752	610	603
22.5cm	531	672	548	575
30cm	424	620	470	571
P Value	**0.02**	**0.022**	**0.012**	**NS**
LSD (5%)	**87**	**82**	**76**	**48**

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Shoot density was also reduced at the widest row spacing compared to the narrowest row spacing at both sites. This trend continued for final head density at Woomelang but not at St Arnaud (Table 2b). Despite these differences in crop structure there were no significant differences in grain yield at either site, but at Woomelang, Commander's yield ranking relative to other varieties was higher at 15cm spacing than at 22.5 or 30cm row spacing (Table 2c).

Grain quality at Woomelang was Malt 1 category for all treatments and was not affected by row spacing except that there was spacing by herbicide interaction for protein (Table 2d). At St Arnaud, plump grain retention at the 15cm spacing was significantly lower than for both the wider spacings (22.5 and 30cm) and protein content at 15cm spacing was higher than at 30cm spacing. Screenings were also increased at 15cm spacing. Consequently quality classification was affected by row spacing with 15cm spacing resulting in the poorest quality grain (Table 2d).

Table 2c. Effect of row spacing on grain yield of barley. The means are calculated from all treatments for each spacing.

Row spacing	Yield t/ha	
	W'lang[1]	StArn'd
15cm	3.19	3.11
22.5cm	3.24	3.40
30cm	3.16	3.27
P Value	**NS**	**NS**
LSD (5%)	**0.32**	**0.56**

[1] *Row spacing x variety interactions were significant. Commander's yield ranking relative to other varieties was higher at 15cm than at 22.5 or 30cm row spacing.*

Table 2d. Effect of row spacing on grain quality parameters of barley. The means are calculated from all treatments for each spacing.

Row spacing	Plump grain retention > 2.5mm[1] %		Screenings < 2.2mm[1] %		Protein[1] % dry basis	
	W'lang	StArn'd	W'lang	StArn'd	W'lang[2]	StArn'd
15cm	87.4	52.8 (F1)	3.3	7.5 (M2)	11.5	12.7 (M3)
22.5cm	88.2	58.3 (M3)	2.9	6.5	10.9	12.4 (M3)
30cm	88.7	62.9 (M2)	3.8	6.0	10.6	12.0
P Value	**NS**	**0.006**	**NS**	**0.007**	**NS**	**0.02**
LSD (5%)	**1.8**	**4.8**	**1.86**	**0.75**	**1.2**	**0.47**

[1] *Barley quality grade for each quality parameter in brackets M2 = Malt2, M3 = Malt3, F1 = Feed1. No bracket indicates Malt 1*

[2] *Row spacing x herbicide interactions were significant*

What were the effects of weed management and pre-emergent herbicide?

Woomelang

Significant differences in brome densities for weed management treatments indicate that the desired weed population differences were achieved. The +Brome treatment had a mean early season brome population of 18.6 plants/m^2 compared to –Brome 2.1 plants/m^2 (P=0.004, LSD 9.8). Both the early season brome population and brome seed set (measured by brome panicle counts prior to harvest) were influenced by row spacing and variety as well as weed management (Table 3a). There was a significant interaction with row spacing and weed management for late season brome (Table 3a). –Brome which included a pre-emergent herbicide treatment and did not have brome seed spread, had the lowest brome population at 30cm spacing whereas the +Brome treatment had the highest brome count at 30cm spacing.

Weed management affected crop growth (Table 3b). Barley plant and shoot densities were reduced in the –Brome treatment as a result of pre-emergent herbicide use. Visual crop effect from herbicide was also evident in this treatment. This trend continued through to head density but was weaker. There were no significant yield effects or quality effects of weed management except for a weed management by protein interaction.

Table 3a. Influence of weed management (-Brome and + Brome), row spacing and variety on early and late season brome grass populations at Woomelang.

Treatment	Early brome (plants/m ^{2})			Late brome (heads/m^2)		
	-Brome	+Brome	Mean	-Brome	+Brome	Mean
Row spacing						
15cm	1.7	12.1	**6.9**	2.7	21.1	**11.9**
22.5cm	3.1	15.9	**9.5**	5.5	33.6	**19.5**
30cm	1.6	27.9	**14.7**	0.8	65.6	**33.2**
P Value	**NS**		**0.059**	**0.045**		**0.08**
LSD (5%)	**12.9**		**6.4**	**24.1**		**19.6**
Variety						
Buloke	1.1	17.4	**9.1**	2.1	37.5	**19.8**
Commander	2.8	9.4	**6.1**	2.6	28.1	**15.4**
Hindmarsh	2.1	28.7	**15.4**	3.1	49.0	**26.0**
SloopVic	2.5	19.0	**10.8**	4.2	45.8	**25.0**
P Value	**0.10**		**NS**	**NS**		**NS**
LSD (5%)	**13.0**			**27.0**		**14.5**

Table 3b. Effect of weed management on crop performance at Woomelang.

Weed Management	Plant density /m^2	Shoot density /m^2	Head density /m^2	Yield[1] t/ ha
+Brome No pre-emergent herbicide, brome spread	137	549	557	3.15
-Brome TriflurX 1.5L/ha + Lexone 140g/ha,very low Brome	127	461	528	3.24
P Value	**0.006**	**0.002**	**0.085**	**NS**
LSD (5%)	**6.6**	**47**	**31**	**0.16**

[1] *Significant variety x weed management interaction*

St Arnaud

The desired weed population differential was achieved at St Arnaud, with significant differences between weed management treatments for early season ryegrass score and for late season ryegrass head density (Table 4a). Ryegrass populations were greater in the header trail area than in the general plot area.

There were no significant differences in early season ryegrass score or late season ryegrass head density for variety or row spacing in the general plot area. Late season ryegrass head density in the header row was measured only in the +Ryegrass treatments. Again no row spacing or varietal effects were evident.

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Table 4a. Effect of weed management on the annual ryegrass population at St Arnaud

Weed Management	Header trail		General plot area	
	Early season ryegrass score (1-10)[1]	Late season ryegrass (heads/m²)	Early season ryegrass score (1-10)[1]	Late season ryegrass (heads/m²)
+Ryegrass No pre-emergent herbicide, high ryegrass	5.7	467	1.5	66.1
-Ryegrass Boxer Gold 2.5L/ha, high ryegrass	2.2	Not recorded	1.0	14.9
P Value	**<0.001**		**0.005**	**0.004**
LSD (5%)	**0.83**		**0.3**	**28.5**

[1] ***ARG score*** *1-approx 50 plants/m²; 2-approx 1000 plants/m² ;5 -approx 2000 plants/mv and 10 -approx 3000 plants/m².*

Plant density was not affected by weed management treatment, nor was shoot density measured in the general plot area (Table 4b). However, shoot density was lower in the header rows compared to the general plot area. Head density was significantly lower for the +Ryegrass treatment and yield was also significantly lower. Protein and screenings were unaffected by weed management but plump grain retention was higher in the +Ryegrass treatment (P=0.02).

Table 4b. Effect of weed management on crop performance at St Arnaud.

Weed Management	Plant density/m²	Shoot density/m²	Head density/m²	Yield[1] t/ ha
+Ryegrass No pre-emergent herbicide, high ryegrass	144	686 (491)[1]	561 (384) [1]	3.43
-Ryegrass Boxer Gold 2.5L/ha, low ryegrass	145	667	605	3.08
P Value	**NS**	**NS**	**0.089**	**0.044**
LSD (5%)	**8.7**	**61**	**52**	**0.34**

[1]Number in brackets is measured in the header trail area and are not included in the statistical analysis

What were the effects of N management at Woomelang?

There was 43kg/ha of available soil N (0 – 100cm) measured at the site in February. This had increased to 75kg N/ha by sowing. The addition of a further 40kg/ha N applied at sowing significantly increased plant density, shoot density and dry matter production but did not result in a significant yield response (Table 5a). The varieties varied from late tillering to GS30 – the time of the 'GS30' N application (40kg/ha N). The addition of N at GS30 resulted in a significant increase in yield. Protein content was elevated but not enough to cause down grading. Grain retention was acceptable for all treatments and screenings were in the vicinity of 3% for each N treatment with no significant differences.

Table 5a. Effect of N management on plant density (GS14), shoot density and dry matter at early GS30 and yield and quality at Woomelang. Mean of all variety treatments for each N treatment.

N treatment	Plant density /m^2	Shoot density /m^2	Dry matter t/ha	Yield t/ha	Plump grain retention > 2.5mm %	Protein dry basis %
Nil	130	372	0.51	2.90	89.8	10.78
40N GS00	148	436	0.65	3.04	87.8	11.89
40N GS30	135[1]	338[1]	0.58[1]	3.21	89.7	11.39
P Value	**0.06**	**<0.001**	**<0.001**	**<0.001**	**0.007**	**<0.001**
LSD (5%)	**15.7**	**47.5**	**0.06**	**0.18**	**1.6**	**0.52**
N x variety	**NS**	**NS**		**0.067**	**NS**	**NS**

[1]*No N applied at time of assessment*

Only Hindmarsh and Flagship exhibited any notable yield response to N applied at GS00 although the differences among varieties were not statistically significant (Table 5b). At GS30, differences among varieties for yield response were statistically significant with Commander and Hindmarsh being the most responsive to N. There was also a strong trend for varieties to respond differently to all 3 N management regimes (P =0.067), with Fleet being relatively non responsive to N regardless of timing and Hindmarsh being highly responsive.

Table 5b. Influence of variety and N management (timing and rate) on grain yield at Woomelang.

Variety	Yield t/ha			Change in Yield from applying 40kg/ha N at	
	Nil	**GS00**	**GS30**	**GS00**	**GS30**
Buloke	2.82	2.99	3.05	0.14	0.2
Commander	2.93	3.04	3.44	0.08	0.47
Flagship	3.03	3.30	3.26	0.22	0.19
Fleet	3.35	3.20	3.30	-0.14	-0.02
Hindmarsh	2.83	3.22	3.59	0.36	0.74
Sloop Vic	2.46	2.47	2.62	0.00	0.16
P Value	**0.067**			**NS**	**0.006**
LSD (5%)	**0.32**			**-**	**0.4**

How did varieties differ?

Plant establishment was either close to or greater than the target plant density for each trial, although there were some differences among varieties (Table 6a). Commander had the highest plant emergence at Woomelang WCNth and Hindmarsh was highest at the Woomelang N trial and at St Arnaud. As in previous years, Hindmarsh appeared slower growing in the first 4 weeks but this was less evident after mid tillering. Shoot densities differed significantly among varieties with Sloop Vic having the lowest shoot density (and therefore lowest yield capacity) in each trial. Hindmarsh was well tillered in all 3 trials. Commander shoot densities at both Woomelang trials may have been underestimated due to sampling being conducted when the earlier maturing varieties had just reached GS30 which would have meant Commander was only late tillering.

Table 6a. Plant and shoot density for all varieties at Woomelang and St Arnaud Mean of all treatments for each variety

Variety	Plant density/m^2			Shoot density/m^2		
	WCNth	N	WCSth	WCNth	N	WCSth
	W'lang	W'lang	StArn'd	W'lang	W'lang	StArn'd
Buloke	129	134	142	500	392	667
Commander	142	136	142	481[1]	356[1]	690
Flagship		134			356	
Fleet		137			379	
Hindmarsh	130	148	153	598	436	773
Sloop Vic	127	136	142	441	372	596
P Value	**0.007**	**0.006**	**0.05**	**<0.001**	**<0.001**	**<0.001**
LSD (5%)	**9.4**	**15.6**	**9.6**	**46.8**	**67.5**	**60.5**
Row spacing x variety	**NS**	**NS**	**NS**	**0.046**	**NS**	**NS**
Weed x variety	**NS**	**-**	**NS**	**NS**	**-**	**NS**
N x variety	**-**	**NS**	**-**	**-**	**NS**	**-**

[1]*Commander may not have finished tillering at the time of assessment.*

As expected, differences in grain yield among varieties were highly significant at each site (Table 6c). In the most favourable season of the project, Hindmarsh and Commander yielded well, Buloke was variable and Sloop Vic was consistently lower than the other varieties. Flagship and Fleet both yielded well in the N trial. Grain quality was very good at Woomelang with only slight varietal differences. At St Arnaud however Buloke and Sloop Vic's plump grain retention was well below malt requirements. Sloop Vic had a tendency for higher protein at each site. An estimate of gross income based on grain yield and quality achieved in each trial illustrates that the achievement of Malting quality had a major influence on income in 2009 (Table 6d). Hindmarsh is currently classified as feed and despite its high yielding status only generated gross income similar to the poorer yielding SloopVic. If Hindmarsh achieves malt accreditation it will become the highest earner of the 4 varieties. Commander was the highest earning variety in the 3 trials.

Table 6b. Grain yield of all varieties at 3 trials. Mean of all treatments for each variety.

Variety	W'lang WCNth		W'lang N		St Arn'd WCSth		% 3-trial mean (3.23t/ha)
	Yield t/ha	% site mean	Yield t/ha	% site mean	Yield t/ha	% site mean	
Buloke	3.22	101	2.95	91	3.18	98	96
Commander	3.21	100	3.19	98	3.43	105	101
Flagship			3.29	101			-
Fleet			3.29	101			-
Hindmarsh	3.65	114	3.21	99	3.49	107	107
Sloop Vic	2.71	85	2.52	78	2.93	90	84
P Value	**<0.001**		**<0.001**		**<0.001**		
LSD (5%)	**0.11**		**0.18**		**0.12**		
Row spacing x variety	**0.03**		**-**		**NS**		
Weed x variety	**0.04**		**-**		**NS**		
N x variety	**-**		**0.067**		**NS**		

Table 6c. Grain quality for all varieties at Woomelang and St Arnaud. Mean of all treatments for each variety.

Variety	Plump grain retention > 2.5mm %			Protein dry basis %		
	WCNth	N	WCSth	WCNth	N	WCSth
	W'lang	W'lang	StArn'd	W'lang	W'lang	StArn'd
Buloke	85.6	85.9	42.3 (F) 1	10.7	11.4	12.3
Commander	89.0	88.9	71.2	10.7	11.2	12.2
Flagship		87.4			11.1	
Fleet		91.8			11.2	
Hindmarsh	88.9	91.8	71.0	10.5	10.7	11.9
Sloop Vic	88.9	88.2	47.1(F) [1]	12.1	12.6 (M3) [1]	13.1(F) [1]
P Value	**0.003**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD (5%)	**2.04**	**2.25**	**4.1**	**0.35**	**0.73**	**0.45**
Row spacing x variety	**NS**	**NS**	**NS**	**0.046**	**NS**	**NS**
Weed x variety	**NS**	**-**	**NS**	**NS**	**-**	**NS**
N x variety	**-**	**NS**	**-**	**-**	**NS**	**-**

[1]*Barley quality grade for each quality parameter in brackets M3=Malt3, F1=Feed1. No bracket =Malt 1*

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Table 6d. Theoretical gross income based on yield (Table 6b) and grain quality (Table 6c) for Buloke, Commander, Hindmarsh and Sloop Vic.

Variety[1]	Gross Income ($/ha) [2]			
	W'lang WCNth	W'lang Nitrogen	StArn'd WCSth	Mean of 3 trials
Buloke	580	531	382	497
Commander	578	574	617	590
Hindmarsh if Feed	438	385	419	414
Hindmarsh if Malt	657	578	628	621
Sloop Vic	325	403	352	360

[1] *Buloke, Commander and Sloop Vic all have malt accreditation. Hindmarsh is under evaluation with a final decision expected in 2011.*

[2] *Gross Income = Yield (Table 6b) x Price (Malt $180, Feed $120). Grain quality from Table 6c.*

Interpretation

Row spacing

Early differences in crop structure resulting from row spacing effects did not translate to yield at either site. This is probably due to a combination of trial design and seasonal conditions. The hot, dry finish to the season and resultant spatial variability within each site may have masked some treatment effects. The trial design (which is partially determined by sowing logistics) also makes differences due to row spacing more difficult to detect than differences due to variety or row spacing by variety interactions. Nonetheless, these results give some confidence that in years with similar conditions, wider row spacings can be used without significant yield penalty due to reduced shoot densities. In higher rainfall environments, however, trials conducted by Southern Farming Systems near Geelong have shown 40cm row spacing to reduce yield compared to 20cm spacing for the third consecutive year. This continues a trend of variable yield response to row spacing throughout the project with a trend to wider row spacings only conferring yield penalties in higher yielding environments. Other management aspects such as variety choice have a greater bearing on yield and income generation than row spacing per se.

Weed management

Brome grass populations were between 10 – 30 plants/m^2 where brome was spread and pre-emergent herbicide was omitted. While not yield limiting, these densities resulted in substantial seed set, most notably at the 30cm spacing. However, where populations were very low and a pre-emergent herbicide was used, seed set at the 30cm spacing was far less. This emphasises the importance of ensuring adequate weed control when using wider row spacings.

No such effects were evident at St Arnaud, despite ryegrass populations high enough to reduce yield.

Nitrogen

The application of N at sowing resulted in more even and vigorous plants at the early stages of growth with less evidence of rhizoctonia (which was present throughout the trial at very low levels). The lack of yield response to early N is again most likely due to the sharp finish to the season. A split application may have proven useful this season to provide the early vigour needed to assist with rhizoctonia management without causing excessive growth that does not convert to yield. GS30 application resulted in a significant yield response while varietal differences in the magnitude of the response varied and depended on timing. Commander and Hindmarsh were the most responsive to N applied at GS30. This is the second year where varietal response to N has differed and warrants further investigation.

Variety

In what has been the most favourable season of the project, yet still punctuated with a dry finish, Hindmarsh has again yielded well but Commander was comparable in 2 of the 3 trials. The future of Hindmarsh in the industry hinges on the malt accreditation evaluation. Based on 2009 grain prices, Hindmarsh profitability could increase by $200/ha if classified as Malt rather than Feed. The improved performance of Commander in a more favourable season supports long term NVT results that suggests it is best suited to areas capable of producing 3t/ha or greater. The long term NVT data also suggest the large yield advantage of Hindmarsh seen in lower yielding environments (<2.5t/ha) reduces in higher yielding environments. This was also the experience in this project.

Acknowledgments

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Notes: