Incorporating new herbicide tolerant juncea canola into low rainfall cropping systems in Western Australia

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KEY MESSAGES

- New varieties of herbicide-tolerant juncea canola (Oasis CL and Sahara CL) have performed well in agronomic testing in Western Australia in terms of grain yield for a range of seed rates, nitrogen rates and row spacings.

AIMS

To investigate the agronomic performance of new herbicide tolerant juncea canola cultivars at different seed rates, nitrogen rates and row spacings.

BACKGROUND

Juncea canola (also called canola quality juncea) is a new oilseed crop with similar quality characteristics to normal canola (edible oil with a low level of erucic acid and the meal is an animal feed with low glucosinolates) but is reported to be more suited to dryland environments. Some of the beneficial traits of new juncea canola varieties include pod shatter resistance, unique blackleg resistance, yellow seed colour and improved heat and drought tolerances relative to normal canola.

The Victorian DPI and Viterra (Canada) are currently breeding herbicide tolerant juncea canola *(Brassica Juncea)* varieties. Two juncea canola IT tolerant varieties ‘Oasis CL’ (Coded JO5Z-08920) and Sahara CL (Jo5Z-08960) were commercially released in 2008 in the eastern states.

The Department of Agriculture and Food, Western Australia (DAFWA) is conducting juncea agronomy trials in WA as a part of the National Brassica Juncea Agronomy project funded by GRDC and coordinated by John Sykes, DPI NSW.

METHOD

The trial design was a completely randomised block design with three replicates in three banks. Two IT herbicide tolerant cultivars Oasis CL and Sahara CL were tested at five seed rates (1, 2, 4, 6, 8 kg/ha) and at three row spacings (22, 44, 66 cm). IT open-pollinated canola 44C79 and Oasis CL were tested at four nitrogen rates (5, 30, 60, 90 kg/ha). Trials were sown on 21 May following cereal crops in 2007 at Wongan Hills. There were three separate blocks exploring interaction between: cultivars x seed rate; cultivars x row spacing; and cultivars x nitrogen rate.

Basal treatments for the trial were; 22 cm row spacing, 4 kg/ha juncea canola seed rate and fertiliser 50 kg/ha MAP (or equivalent) was drilled below the seed at seeding in all three blocks. Talstar/endosulphan (bare earth) was applied immediately after seeding for pest control. In the nitrogen rate block, all five nitrogen rates were topdressed before seeding. Ammonium Sulphate (140 kg/ha) was topdressed on both the seed rate and row spacing blocks six weeks after sowing.

Trials were closely monitored and controlled for weeds, insects and diseases throughout the growing season. The in-crop On-duty/Intervix herbicide was applied at the four leaf stage to control broad leaf weeds.

RESULTS

The 2008 season at Wongan Hills started with a late seasonal break in May followed by a dry June and then wet July. The site received 245 mm growing season rainfall (May to October) with a total of 374 mm for the year. Mild temperatures and the good finish to the season improved the juncea canola production. Oil quality data are currently being processed and are not yet available.

Cultivars x Seed rate

The main effects of cultivars and seed rate on plant establishment (plant population) were significant. The mean plant population was higher for Sahara CL (106 plants/m^2) than Oasis CL (64 plants/m^2). Plant establishment increased from 28 to 153 plants/m^2 as seeding rate increased from 1.0 to 8 kg/ha (Table 1). Both cultivars produced similar yields (1.85 t/ha). Grain yield increased with seeding rate (Table 1). Figure 1 illustrates the response of juncea canola grain yield to plant population at Wongan Hills. Juncea canola attained the maximum yield of 2.14 t/ha at a seed rate of 6 kg/ha (with plant population of 122 plants/m^2), suggesting that it may have higher yield potential in medium to high rainfall areas.

Table 1 **Effect of seeding rate on plant establishment (plant population) and grain yield of new herbicide-tolerant juncea canola**

Seed rate, kg/ha	Plants/m^2			Yield, t/ha		
	Sahara CL	Oasis CL	*Average*	Sahara CL	Oasis CL	*Average*
1.0	37	18	*28*	1.60	1.49	*1.55*
2.0	62	33.7	*48*	1.88	1.72	*1.80*
4.0	97	56	*77*	1.80	1.89	*1.85*
6.0	145	99	*122*	1.94	2.09	*2.01*
8.0	191	115	*153*	1.88	2.14	*2.01*
Average	*107*	*64*	*85*	*1.82*	*1.87*	*1.84*
l.s.d. (0.05)						
Cultivars		*14*			*0.17*	
Seed rate		*22*			*0.26*	
*Cultivars*seed rate*		*32*			*0.37*	
CV		*21.5%*			*11.8%*	

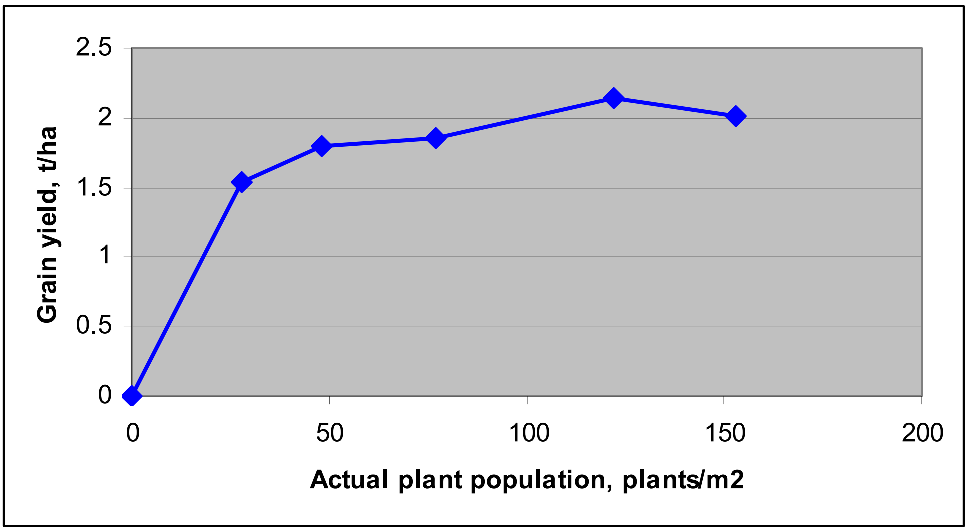

Figure 1 The relationship between juncea canola seeding rate (actual plant population) and grain yield.

Cultivars x row spacing

The main effects of cultivar and row spacing on plant establishment (plant population) were significant but had no effect on grain yield (Table 2). The mean plant population was higher for Sahara CL (48 plants/m^2) compared to Oasis CL (33 plants/m^2). Juncea canola yielded 1.63 t/ha, which was similar for all three row spacings and indicates that juncea canola might not experience a yield penalty if sown in wide rows.

Table 2 **Effect of row spacing on plant establishment (plant population) and grain yield of new herbicide-tolerant juncea canola**

Row spacing, cm	Plants/m^2			Yield, t/ha		
	Sahara CL	Oasis CL	*Average*	Sahara CL	Oasis CL	*Average*
22.0	32	25	*28*	1.72	1.67	*1.70*
44.0	51	33	*42*	1.77	1.56	*1.67*
66.0	61	40	*51*	1.59	1.47	*1.53*
Average	*48*	*33*	*40*	*1.69*	*1.57*	*1.63*
l.s.d. (0.05)						
Cultivars		*11*			*0.23*	
Row spacing		*14*			*0.33*	
*Cultivars*row spacing*		*20*			*0.46*	
CV		*27.0%*			*17.10%*	

Cultivars x nitrogen rates

Nitrogen rates had no effect on crop establishment or grain yield (Table 3). The mean plant population for 44C79 CL canola was more than twice (73 plants/m^2) that of juncea canola Oasis CL (27 plants/m^2). Similarly 44C79 CL canola yielded better 1.84 t/ha than juncea canola 1.25 t/ha.

Table 3 Nitrogen rate effects on plant establishment (plant population) and grain yield of new herbicide-tolerant oilseeds, juncea canola (Oasis CL) and canola (44C79 CL)

Nitrogen rate, kg N/ha	Plants/m^2			Yield, t/ha		
	44C79 CL	Oasis CL	*Average*	44C79 CL	Oasis CL	*Average*
5.0	79	26	*52*	1.66	1.12	*1.39*
30.0	72	26	*49*	1.86	1.20	*1.53*
60.0	80	28	*54*	2.04	1.30	*1.67*
90.0	62	30	*46*	1.80	1.36	*1.58*
Average	*73*	*27*	*50*	*1.84*	*1.24*	*1.54*
l.s.d. (0.05)						
Cultivars		*10*			*14*	
Nitrogen rate		*14*			*22*	
*Cultivars*nitrogen rate*		*19*			*32*	
CV		*22.0%*			*21.50%*	

CONCLUSION

Based on limited testing in the WA environment, the new herbicide-tolerant juncea canola shows promise from a grain yield perspective and may provide an alternative oilseed species. Further field evaluation of new herbicide-tolerant juncea canola is needed across a range of environments and seasons in Western Australia to determine if it can become a profitable break crop in cereal rotations.

KEY WORDS

canola (*Brassica napus*), varieties, cultivars, canola quality juncea or juncea canola (*Brassica juncea*) agronomy, grain yield, oil

ACKNOWLEDGMENTS

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Varietal differences in germ end staining of barley

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KEY MESSAGES

- The varieties Gairdner, Hamelin, Baudin and breeding line WABAR2315 suffered less germ end staining than other malt varieties.
- Hindmarsh, Commander and Stirling were the varieties worst affected.

AIMS

To assess the current range of malt barley varieties for germ end staining of grain.

INTRODUCTION

The precise cause of germ end staining or black point, in barley, is still unknown. While fungal growths of *Alternaria* species were initially believed to be responsible and do cause other forms of grain discolouration, fungi do not cause germ end staining in barley. Current theory is that oxidised phenol activity during grain ripening may be responsible although how this relationship affects the level of germ end staining in barley is unknown (Sulman et al. 2001a). What is known however is that humid environmental conditions during ripening result in the development of germ end staining and that varieties exhibit different levels of resistance (Sulman et al. 2001b). In the current WA barley variety guidelines, No ratings have previously been published for susceptibility to germ end staining, however impact on grain quality can affect the grade that grain is accepted into and hence payment received by growers.

METHOD

Two types of trials in the medium and high rainfall zones; barley variety x time of sowing (TOS) and malt variety x nitrogen, were opportunistically assessed for germ end staining by a CBH trained technician according to the definition provided by CBH Ltd (November 2008). Trial designs were randomised blocks with three replicates per treatment.

One hundred grains per plot were subsampled and results multiplied by four to compare results directly with CBH limits. Test comparisons between counts of 100 and 400 grains showed that using 100 grains provides a reliable estimate. Counts of 100 grains were therefore used for the sake sample through put.

For the 2008/09 harvest, grain accepted into the CBH Malt 1 segregation must have no more than 45 grains out of 400 affected by germ end staining and no more than 60 affected per 400 for Malt 2. Only the results for malt varieties or potential malt varieties are presented here as there is no germ staining limit for feed grades.

Lines assessed were Stirling, Baudin, Buloke, Flagship, Gairdner, Hamelin, Vlamingh, Hannan, Hindmarsh, WABAR2315 and Commander (formerly known as WI3416-1572).

Table 1 **Details of trials assessed for germ staining (location, date of sowing and date of harvest)**

Location	Trial type	Date(s) of sowing	Date of harvest
Gibson	Variety x TOS	27 May 2008 19 June 2008 15 July 2008	8 December 2008
Gibson	Malt variety x N (0, 20 60 kg N/ha @ tillering)	26 May 2008	7 December 2008
Wittenoom Hills	Variety x TOS	21 May 2008 11 June 2008 1 July 2008	22 December 2008
Newdegate	Variety x TOS	19 May 2008 10 June 2008 3 July 2008	23 December 2008
Jacup	Malt variety x N (0, 20 60 kg N/ha @ tillering)	26 May 2008	8 January 2009

RESULTS

Environmental conditions in 2008

The 2008 season offered ideal conditions for the development of germ end staining during grain ripening in November in the lower wheatbelt and south coast. The contrast between rainfall in November 2008 and November 2007, where no germ end staining was observed is shown in Figure 1 below. At each site the minimum and maximum relative humidity for November were also higher in 2008 than in 2007 or for the long term average (data not shown).

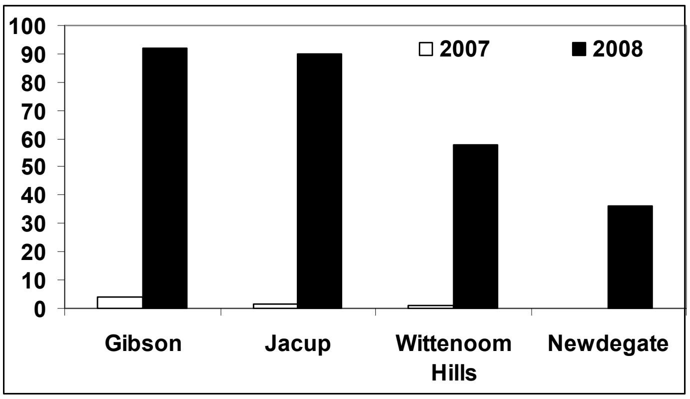

Figure 1 November rainfall (mm) for trial sites in 2007 and 2008.

Varietal differences

Each site showed different levels of staining although they were not directly related to the amount of rainfall received in November. The order of staining severity was Gibson > Wittenoom Hills > Jacup >> Newdegate. Results here will focus on Gibson and Wittenoom Hills.

At Gibson Hindmarsh, Stirling and Flagship were the worst affected on average while Gairdner, Hamelin and Baudin were least affected (Table 2).

At Wittenoom Hills Hindmarsh, Buloke, and Stirling were the worst affected on average while Gairdner, Hamelin, WABAR2315 and Baudin were the least affected (Table 3).

Overall, the most consistently susceptible variety appears to be Hindmarsh, followed by Commander and Stirling. Gairdner, Hamelin and WABAR2315 are more resistant to germ end staining.

Table 2 **Number of grains affected by germ end staining per 400 grains at Gibson in 2008 for three times of sowing (TOS). Figures in bold indicate greater than 45 grains/400 affected**

	Time of sowing		
Variety	**27 May**	**19 June**	**15 July**
Stirling	**229**	**48**	**56**
Baudin	**52**	10	40
Buloke	**74**	**98**	8
Flagship	**261**	38	16
Gairdner	36	4	6
Hamelin	**61**	0	2
Vlamingh	**101**	0	8
Hannan	**117**	44	20
Hindmarsh	**362**	22	**46**
WABAR2315	**80**	24	18
Commander	**122**	24	40
Average	136	28	24
ANOVA	**Significance**	**l.s.d. (0.05)**	
tos	p = 0.012	37	
variety	p = < 0.001	42	
tos.variety	p = < 0.001	73	

Table 3 **Number of grains affected by germ end staining per 400 grains at Wittenoom Hills in 2008 for three times of sowing (TOS). Figures in bold indicate greater than 45 grains/400 affected**

	Time of sowing		
Variety	**21 May**	**11 June**	**1 July**
Stirling	**72**	45	31
Baudin	29	37	23
Buloke	**88**	27	40
Flagship	44	9	44
Gairdner	**47**	20	21
Hamelin	36	31	20
Vlamingh	44	44	16
Hannan	24	**88**	27
Hindmarsh	**57**	**71**	35
WABAR2315	44	25	20
Commander	32	**53**	39
Average	47	41	29
ANOVA	**Significance**	**l.s.d. (0.05)**	
tos	ns		
variety	p = 0.029	30	
tos.variety	ns		

Effect of nitrogen

The rate of nitrogen applied did not affect the development of germ end staining in the varieties tested.

Effect of time of sowing

Time of sowing significantly affected germ end staining at Gibson (Table 2), but not at Wittenoom Hills (Table 3). At Gibson, the first time of sowing was severely affected and many varieties exceeded accepted limits, relegating them to feed grade. Second and third times of sowing generally had lower levels of staining. There was also a highly significant interaction between time of sowing and variety ($p < 0.001$) at Gibson and including average maturity time as a covariate did not alter this interaction. There was no statistical significance between germ staining levels within varieties at different times of sowing at Wittenoom Hills, however there was a slight trend towards less germ staining with later sowing.

CONCLUSION

The WA malting varieties Gairdner, Baudin and Hamelin all appear to have good levels of resistance to germ end staining, along with the potential new malt line WABAR2315. The high yielding variety Hindmarsh appeared to be the most susceptible variety tested.

While early sowing in the time of sowing trial resulted in higher levels of germ end staining there was no affect of nitrogen rate on germ end staining in an accompanying nitrogen rate trial in Gibson.

KEY WORDS

barley, germ end staining

ACKNOWLEDGMENTS

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Wheat variety performance in the Central Agricultural Region in 2008

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KEY MESSAGES

- The yields and gross returns of several newer APW varieties, including the more recently released varieties Mace and Magenta, was comparable, if not better than Wyalkatchem at some times of sowing across three sites at Corrigin, Merredin and Wongan Hills. Likewise the performance of the three new noodle wheats, Binnu, Fortune and Yandanooka was comparative to that of Calingiri.
- The average yield with late May sowing at Wongan Hills was 37% higher than the average yield with 3 July sowing. Average yield with mid May sowing at Corrigin was 41% higher than with late June sowing. Average grain yields at Merredin did not differ significantly between sowing times.
- The screenings levels of Binnu did not differ distinctly from those of the other noodle varieties, even with the later sowing times.
- High screenings and low hectolitre weight were not an issue at any of three trial locations in 2008.

AIMS

To investigate the performance of new wheat varieties at different sowing times in the central agricultural region in 2008.

METHOD

Three field trials were conducted at Corrigin, Merredin and Wongan Hills in 2008. Twenty–four wheat breeding lines from various Australian breeding companies were sown at three times of sowing in a randomised block design with three replications. The first time of sowing (TOS), at Merredin (Agzone 4), was sown on 29 April after a good rain to generate information on early sowing. A light irrigation was applied in May to save the crop due to a very dry spell. Germination in TOS1 at Merredin was patchy compared to TOS 2 and TOS 3. Grain yield was limited by frost damage in all time of sowings at Merredin. At Wongan Hills (Agzone 2) TOS 1 was in late May but the second and third time of sowing was delayed until 15 June and 3 July respectively, when rainfall allowed. At Corrigin (Agzone 2) TOS 1 was 12 May. Subsequent sowings were at 20 and 25 days after, when rainfall permitted. Soil type and crop rotation for the three sites were as follows: Wongan Hills a sandy loam following pasture, Corrigin following canola and at Merredin a clay loam following pasture.

Data on grain yield, grain protein, hectolitre weight and screenings were recorded and analysed using Genstat.

Note: Screenings include whole and cracked grain. Gross income was calculated on the average yield and quality for each treatment using cash price. Base scale: APW $292.5. Grade spreads: H2 +$12, AUH2 -$5, ASW1 -$25, ASFT +$25, ANW1 -$25, ANW2 -$35, AGP1 -$30.

RESULTS

April-October rainfall was 277.8 mm at Corrigin, 282.6 mm at Merredin and 301.2 mm at, Wongan Hills. Minimum rainfall was recorded in the month of August at all trial sites. However, significant rainfall was received in September/October at all locations.

Yield and grain quality results are presented in Table 1 for Corrigin, Table 2 for Merredin and Table 3 for Wongan Hills. Sowing times had a significant effect on grain yield and protein at both Corrigin and Wongan Hills but not at Merredin.

The soft wheat EGA 2248 was the highest yielding variety at Corrigin, followed by Magenta and Carnamah. EGA 2248 only met protein standards for soft wheat when sown in late May. The newly released variety Mace, Fang and Fortune were among the top performers at this site. Mace offers excellent resistance to stem, stripe and leaf rust. Most of the noodle varieties achieved the delivery standard of 9.5–11.5% protein at all time of sowings (Table 1). None of the eligible varieties met the minimum delivery standards for AH or APW with late May sowing. The gross returns of Carnamah, Magenta, Mace, Yitpi and EGA2248 were higher than that of Correll, Fang, Gladius, Espada and Fortune.

There was no significant difference between yields of the top yielding varieties Espada, Gladius, EGA Wentworth, Bumper, Derrimut and RAC1423 with late April sowing at Merredin (Table 2). While the grain yields of the newly released variety Bumper were comparable those of the top yielding varieties at this site the gross returns were below the higher gross returns recorded. The gross returns of the durum wheat variety Jandaroi were amongst the highest with 18 June and 18 July sowing. Most of the AH varieties achieved protein levels in excess of 13% in TOS 2 and TOS 3. All noodle wheat varieties recorded protein levels above 11.5% at all times of sowing. All varieties had consistently low screenings (< 5%) and high hectolitre weight (> 74 kg/kL).

The newly released varieties Mace and Fortune were among the top yielders, including Magenta, Yandanooka, Binnu, Yitpi, Young and Wyalkatchem at Wongan Hills (Table 3). The yield of Fortune was comparable to Arrino, Binnu, Calingiri and Yandanooka. Grain protein levels for all noodle varieties grown at Wongan Hills were within the delivery standards at all times of sowings except for Binnu and Fortune in TOS1. The gross income of Magenta, Yitpi and Mace was higher than for Tammarin Rock, Carnamah, EGA Bonnie Rock and Wyalkatchem. All of the varieties had low screenings and hectolitre weight exceeding the 74 kg/hl minimum standard.

CONCLUSION

The results presented in this paper justify consideration of some of the new wheat varieties as replacements for commercial favourites in the central agricultural region. Mace and Magenta were notably amongst the most consistent varieties in terms of gross returns across times of sowing at Corrigin and Wongan Hills. On the whole the three new noodle varieties Binnu, Fortune and Yandanooka performed comparatively with Calingiri across times of sowing and sites.

KEY WORDS

wheat varieties, wheat agronomy, time of sowing, grain yield, protein, screenings, hectolitre weight

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Table 1 **Effect of sowing time on yield, quality and economic returns of wheat varieties at Corrigin in 2008**

Grade	Variety	Grain yield (t/ha)			Mean	Protein (%)			Mean	Screenings (%)			Mean	Gross income ($/ha)		
		12 May	4 June	24 June	(t/ha)	12 May	4 June	24 June	(%)	12 May	4 June	24 June	(%)	12 May	4 June	24 June
AH	Carnamah	2.61	1.40	1.44	1.82	8.9	11.8	11.1	10.6	1.2	1.5	3.2	2.0	795	426	438
	EGABonnieRock	2.39	1.23	1.11	1.58	9.7	13.0	12.7	11.8	1.1	0.7	1.1	1.0	728	375	338
	Yitpi	2.41	1.50	1.34	1.75	9.6	12.8	11.5	11.3	2.3	1.6	2.8	2.2	734	457	408
APW	Axe	1.55	1.12	1.05	1.24	10.6	12.8	12.8	12.1	0.6	1.0	0.6	0.7	453	328	307
	Carinya	2.04	1.31	1.36	1.57	9.1	12.2	11.0	10.8	0.9	0.5	1.2	0.9	584	383	398
	Catalina	1.44	1.30	1.35	1.36	9.4	11.8	10.8	10.7	1.1	0.5	0.9	0.8	417	380	395
	Correll	2.23	1.36	1.53	1.71	9.4	12.2	11.0	10.9	2.4	0.8	2.1	1.8	646	398	448
	DerrimutWt	2.22	1.35	1.39	1.65	9.0	11.5	10.1	10.2	1.4	1.2	2.2	1.6	636	395	407
	Espada	2.20	1.37	1.44	1.67	9.9	12.3	11.3	11.2	1.3	0.8	2.1	1.4	644	401	421
	Fang	2.22	1.39	1.48	1.70	9.0	11.7	10.3	10.3	1.0	1.5	2.2	1.6	636	407	433
	Gladius	2.35	1.33	1.37	1.68	9.8	12.3	12.0	11.4	1.4	0.9	1.7	1.3	687	389	401
	Magenta	2.27	1.57	1.70	1.85	9.6	12.2	10.5	10.8	1.6	1.8	1.7	1.7	657	459	497
	Mace	2.65	1.39	1.43	1.82	8.6	12.1	10.7	10.5	1.7	0.4	2.4	1.5	759	407	418
	Young	2.29	1.43	0.79	1.50	9.9	12.1	11.7	11.2	1.0	0.5	1.2	0.9	670	418	231
	LR Lincoln	1.43	1.20	1.36	1.33	9.7	12.9	11.1	11.2	2.3	0.7	1.9	1.6	418	351	398
	Wyalkatchem	2.48	0.95	1.26	1.56	8.9	13.2	11.3	11.1	0.9	0.5	1.4	0.9	711	278	369
	Zippy	2.13	1.14	0.91	1.39	10.3	12.4	13.1	11.9	1.6	0.5	0.5	0.9	623	333	266
ASFT	EGA2248	2.9	1.4	1.35	1.88	9.0	12.3	11.5	10.9	0.3	0.2	0.7	0.4	921	361	348
ASWN	Arrino	2.47	1.38	1.30	1.72	9.7	12.1	11.5	11.1	0.5	0.3	0.7	0.5	636	355	335
	Binnu	2.48	1.32	1.30	1.70	9.2	11.4	10.5	10.4	1.0	0.5	3.1	1.5	639	340	335
	Calingiri	2.29	1.52	1.46	1.76	9.6	11.6	10.5	10.6	1.0	0.9	2.6	1.5	590	391	376
	Yandanooka	2.13	1.29	1.36	1.59	9.5	12.5	11.1	11.0	1.5	0.4	2.1	1.3	548	332	350
	Fortune	2.39	1.54	1.46	1.80	9.1	11.5	11.1	10.6	1.3	0.5	2.8	1.5	615	397	376
Unclassified	RAC 1423	2.07	1.33	1.23	1.54	10.1	12.8	11.5	11.5	1.1	1.1	2.7	1.6			
	Average within each TOS	2.24	1.34	1.32	1.63	9.48	12.2	11.3	11.0	1.3	0.8	1.8	1.3			
	TOS (l.s.d.)	0.24				0.2				1.1						
	Var (l.s.d.)	0.32				0.3				0.6						
	Var (l.s.d.) between TOS	0.54				0.6				1.3						
	Var (l.s.d.) within TOS	0.52				0.6				0.9						
	%CV	19.9				3.3				38						

Table 2 **Effect of sowing time on yield, quality and economic returns of wheat varieties at Merredin in 2008**

Grade	Variety	Grain yield (t/ha)			Mean (t/ha)	Protein (%)			Mean (%)	Screenings (%)			Mean (%)	Gross income ($/ha)		
		29 April	18 June	18 July		29 Apr	18 June	18 July		29 April	18 June	18 July		29 April	18 June	18 July
APDR	Jandaroi	1.01	1.19	1.09	1.10	14.7	15.5	14.9	15.0	1.5	2.4	2.4	2.1	396	467	428
	Carnamah	1.22	1.26	1.45	1.31	13.1	14.6	12.3	13.3	5.1	3.3	5.0	4.5	371	384	442
AH	EGABonnieRock	1.49	1.16	1.37	1.34	12.8	13.8	13.3	13.3	2.8	3.3	3.9	3.3	454	353	417
	TammarinRock	1,53	1.21	1.20	1.21	12.0	13.7	13.2	13.0	4.3	2.6	4.6	3.8	466	368	365
	Yitpi	1.54	1.19	1.22	1.32	11.5	15.3	14.3	13.7	5.3	5.0	4.5	4.9	469	362	371
	Axe	1.51	1.31	1.15	1.32	12.4	12.9	13.7	13.0	4.6	5.0	4.1	4.6	442	383	336
	EGA Bounty	1.20	1.22	1.21	1.21	12.6	13.7	13.5	13.3	2.4	3.9	1.4	2.6	351	357	354
	Catalina	1.32	1.28	1.30	1.30	12.5	13.4	13.1	13.0	2.4	2.5	2.6	2.5	386	374	380
	Correll	1.14	1.23	1.24	1.20	12.9	14.1	13.5	13.5	3.6	5.0	2.9	3.8	333	360	363
	DerrimutWt	1.68	1.42	1.19	1.43	12.0	13.9	13.3	13.1	3.5	4.5	5.3	4.4	491	415	348
	Endure	1.15	1.51	1.15	1.27	13.3	13.4	14.6	13.8	1.9	3.3	1.3	2.2	336	442	336
	Espada	1.60	1.52	1.40	1.51	12.4	13.6	13.8	13.3	4.9	4.6	5.1	4.9	468	445	410
APW	Gladius	1.51	1.53	1.45	1.50	12.8	13.5	14.5	13.6	4.6	3.9	5.3	4.6	442	448	424
	Magenta	1.59	1.24	1.22	1.35	12.5	14.2	14.5	13.7	4.6	5.3	3.3	4.4	465	363	357
	Mace	1.62	1.29	1.21	1.37	12.5	14.2	13.2	13.3	3.5	3.2	3.5	3.4	474	377	354
	EGAWentworth	1.57	1.37	1.52	1.49	11.8	13.2	13.2	12.7	2.5	5.3	2.5	3.4	459	401	445
	Young	1.44	1.37	1.30	1.37	12.5	13.5	13.5	13.2	3.4	3.4	6.0	4.3	421	401	380
	LR Lincoln	1.45	1.27	1.26	1.33	12.2	13.8	13.5	13.2	5.0	4.2	4.7	4.6	424	371	369
	Wyalkatchem	1.39	1.12	1.34	1.28	13.0	14.4	13.5	13.6	1.9	2.4	2.8	2.4	407	328	392
	Zippy	1.51	1.20	1.05	1.25	12.9	14.5	14.2	13.9	2.7	1.6	2.2	2.2	442	351	307
	Binnu	1.48	1.25	1.43	1.39	12.6	13.4	12.3	12.8	2.2	2.5	3.3	2.7	381	322	368
ASWN	Calingiri	1.41	1.38	1.24	1.34	12.2	13.1	13.8	13.0	2.3	5.2	4.0	3.8	363	355	319
ASW	Bumper	1.49	1.46	1.36	1.44	12.1	13.5	13.1	12.9	5.0	4.9	5.7	5.2	399	391	364
Unclassified	RAC 1423	1.48	1.40	1.43	1.44	12.8	14.0	12.8	13.2	4.0	4.0	4.6	4.2			
	Average within each TOS	1.43	1.31	1.28	1.34	12.6	13.9	13.6	13.3	3.7	3.8	3.8	3.8			
	TOS (l.s.d.)	0.53				2.1				1.3						
	Var (l.s.d.)	0.18				0.9				1.1						
	Var (l.s.d.) between TOS	0.54				2.3				2.1						
	Var (l.s.d.) within TOS	0.31				1.5				1.8						
	%CV	14				7.4				16						

Table 3 **Effect of sowing time on yield, quality and economic returns of wheat varieties at Wongan Hills in 2008**

Grade	Variety	Grain yield (t/ha)			Mean	Protein (%)			Mean	Screenings (%)			Mean	Gross income ($/ha)		
		23 May	15 June	3 July	(t/ha)	23 May	15 June	3 July	(%)	23 May	15 June	3 July	(%)	23 May	15 June	3 July
AH	Carnamah	3.13	1.86	1.82	2.27	9.4	11.0	10.5	10.3	4.3	3.8	5.5	4.5	953	566	554
	EGABonnieRock	3.30	1.79	1.67	2.25	9.9	11.7	11.3	11.0	3.2	2.6	4.1	3.3	1005	545	509
	TammarinRock	3.29	1.78	1.81	2.29	9.6	10.8	10.6	10.3	3.8	3.4	4.7	4.0	1002	542	551
	Yitpi	3.22	1.75	2.18	2.38	10.0	11.1	10.5	10.5	4.7	5.5	5.0	5.0	980	533	664
APW	Axe	2.81	1.90	2.09	2.27	9.8	10.9	10.8	10.5	3.3	3.9	3.5	3.6	822	556	611
	Carinya	3.03	1.97	1.86	2.29	9.7	11.1	10.3	10.4	1.4	2.3	3.5	2.4	886	576	544
	Catalina	3.07	1.82	2.10	2.33	9.5	11.0	10.3	10.3	3.1	2.3	4.0	3.1	898	532	614
	Correll	2.75	1.80	2.35	2.30	10.2	10.6	10.2	10.3	4.1	6.0	5.5	5.2	804	527	687
	DerrimutWt	3.35	1.62	1.85	2.27	8.6	10.4	10.0	9.7	3.5	5.4	6.4	5.1	963	474	541
	Espada	3.07	1.63	1.81	2.17	9.5	10.9	10.7	10.4	3.0	4.0	4.7	3.9	898	477	529
	Gladius	3.13	1.70	2.14	2.32	8.9	11.6	10.8	10.4	3.5	3.9	3.2	3.5	900	497	626
	Magenta	3.37	2.07	2.39	2.61	9.3	11.5	10.0	10.3	4.5	4.6	4.8	4.6	969	605	699
	Mace	3.35	1.74	2.18	2.42	8.5	11.2	10.1	9.9	2.4	2.8	4.2	3.1	963	509	638
	EGAWentworth	3.13	1.89	1.74	2.25	9.5	11.0	10.3	10.3	2.5	3.4	4.6	3.5	916	553	509
	Young	3.16	2.06	1.80	2.34	9.1	10.5	10.8	10.1	2.4	2.6	3.9	3.0	909	603	527
	LR Lincoln	3.21	1.66	1.96	2.28	9.5	11.1	10.6	10.4	4.5	4.0	3.4	4.0	939	486	573
	Wyalkatchem	3.39	1.74	1.88	2.34	9.1	11.4	10.7	10.4	2.2	1.9	2.2	2.1	975	509	550
	Zippy	2.99	1.77	1.55	2.10	9.6	11.0	11.9	10.8	2.7	2.1	1.4	2.1	875	518	453
ASWN	Arrino	3.00	1.73	1.92	2.22	10.3	11.2	10.2	10.6	1.0	0.9	2.4	1.4	803	463	514
	Binnu	3.36	1.68	2.14	2.39	8.9	10.5	9.7	9.7	2.9	2.7	3.9	3.2	865	433	551
	Calingiri	3.11	1.69	1.99	2.26	9.8	10.7	10.2	10.2	2.9	3.6	4.3	3.6	832	452	532
	Yandanooka	3.16	2.15	2.16	2.49	9.8	11.9	10.1	10.6	2.7	2.0	4.4	3.0	845	575	578
	Fortune	3.19	1.68	2.15	2.34	9.0	10.9	10.4	10.1	2.9	3.1	3.9	3.3	821	433	554
Unclassified	RAC 1423	3.22	1.56	2.15	2.31	10.0	11.2	10.1	10.4	2.8	3.8	4.4	3.7			
	Average within each TOS	3.16	1.79	1.99	2.31	9.5	11.1	10.5	10.3	3.2	3.5	4.2	3.6			
	TOS (l.s.d.)	0.43				0.9				4						
	Var (l.s.d.)	0.22				0.4				0.9						
	Var (l.s.d.) between TOS	0.51				1.1				3.9						
	Var (l.s.d.) within TOS	0.39				0.7				1.7						
	%CV	10.5				4.5				29.3						

Barley variety identification using DNA fingerprinting

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KEY MESSAGES

Single Nucleotide Polymorphisms can be used to successfully identify barley varieties and the technology will be applicable to other crops.

AIMS

Varietal purity is an important commercial driver in the trade of malting barley. Receival standards for malting barley across Australia specify a minimum of 95% varietal purity. Current variety identification methods within the grain trade rely on differentiation by protein molecular weights, but increasingly the industry is confronted with different varieties demonstrating identical protein patterns and inhibiting conclusive varietal identity of a parcel of grain.

DNA based technology, and particularly single nucleotide polymorphisms (SNPs), are potentially a useful commercial tool for conducting variety identification and this project was established to test the feasibility of developing a cost effective commercial test for varietal identity and varietal purity in barley, using SNPs.

BACKGROUND

DNA code is made up of combinations of four nucleotides: Adenine (A), Cytosine (C), Thymine (T) and Guanine (G). Recent research shows that differences in the position of just a single nucleotide can be used as genetic markers or as unique differentiators between different varieties. This difference in the individual nucleotides between two DNA fragments is known as a Single Nucleotide Polymorphism

The use of DNA based fingerprinting for identification is largely based on techniques which make use of anonymous differences in large regions of the DNA sequence. Various types of markers (RAPDs, AFLPs, microsatellites and SNPs) are often useful for distinguishing individuals. They are not necessarily linked to any particular trait and all have advantages and disadvantages for the species over which they are deployed. For a marker to be useful in a commercial test it must be reproducible, cost competitive and suited to high-throughput analysis. It should also preferably have technological longevity. The high frequency of SNPs across a DNA sequence makes them a preferred marker for varietal identification. They are suited to automation through high-throughput analytical platforms and they provide technological longevity, due to the fact that they directly relate to individual DNA bases.

METHOD

SNPs are increasingly being routinely used within genetic studies and breeding programs for quantifying genetic variability and as genetic markers for selection purposes. As such, the technology can be readily applied to individual seeds or plants to type those seeds and plants to a particular variety. However, the cost of testing sufficient individual seeds or plants to be able to confirm the varietal identity of a crop or parcel of grain with an acceptable level of statistical confidence would be commercially prohibitive at current technology costs. Applying this technology to a composite sample of grain or plant material that was sufficiently large enough to provide reasonable representation is more cost effective. For the purposes of developing and testing such an approach, a sample of approx. 1000 seeds has been used.

Using single individual seeds or plants, each SNP loci will call a single base (A, C, T or G) if the individual is homozygous at that locus and will call two bases if it is heterozygous at the locus. For crop varieties that have been released with a high level of homozygosity (e.g. barley), it can be expected that most SNP loci will call a single base. However, when working with the population that makes up a variety, the frequency of loci that call more than one base will increase, reflecting the heterogeneity of the population that makes up the variety.

The cost effective use of this technology relies on identifying loci that are homogeneous within each of two varieties being compared and therefore only call one base, but call a different base for the two varieties. SNP loci which are homogeneous within a variety are defined as informative SNPs for that variety. For a sample to be assessed as a particular variety there should not be any mismatches at any of the informative SNP loci. SNP loci that are informative for two varieties, but call different bases for each variety are defined as discriminating SNPs as they can be use to differentiate between the two varieties.

To date, 45 barley SNPs have been evaluated and 33 of those have been determined to provide reliable data that can be used and the results for those 33 SNPs is reported.

SNP No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
BAUDIN	T	C	T	A	G	T	C	C	A	C	T	A	A	C	A	G	T	C	C	G	C	G	T	A	G	T	A	C	T	A	C	C	A
	A											G			G															C			
GAIRDNER	A	C	T	C	G	T	C	C	A	T	C	A	G	A	A	G	T	C	C	G	T	G	T	A	G	T	A	C	T	C	T	T	G
	T			A						C									T				C							A	C	C	

Figure 1.

The SNP profiles for two barley varieties, Baudin and Gairdner, are shown in Figure 1. For each variety there are SNPs that call only one base (e.g. 2, 3, 4, 5 for Baudin and 2, 3, 5 for Gairdner) and SNPs that call two bases (e.g. 1, 12, 15 for Baudin and 1, 4, 10 for Gairdner). The ones that call only one base are informative SNPs, and represent areas of homogeneity (uniformity) within the variety. These informative SNPs can be used to type a variety.

When comparing Baudin with Gairdner, it can be seen that SNPs 11, 13, 14, 21 and 33 are not only informative for each variety, but different between the varieties. These are discriminating SNPs for these two varieties and can be used to distinguish between them. If the informative SNP profile for a sample matches that of a reference variety and sufficient SNPs are used to ensure the presence of discriminating SNPs between any two varieties within the suite of varieties of interest, it is possible to determine the varietal identity of the sample.

In the case of a mixture of two or more varieties, the varieties present should be able to be identified because they will demonstrate a match for the informative SNPs for each variety but, at those loci that discriminate between the varieties present, both matching bases will be called. In such cases, the technology being used provides the opportunity for estimating the relative frequency of occurrence of each base and if those estimates are accurate, they should provide a pathway for estimating the level of contamination.

To date, this project has evaluated 34 current commercial Australian barley varieties. Initial characterisation of varieties against the 33 SNPs was conducted on reference samples of varieties held by the Australian Winter Cereals Collection in Tamworth NSW. Subsequent testing of that characterisation data is currently being evaluated in a proving trial using variety samples provide by the barley breeding programs and major barley marketing and grain storage companies.

Given that for 34 varieties, there are 1122 possible pair-wise comparisons, software has been written to summarise and interpret the data. With this software it is possible to quickly compare the results for a blind sample against all reference varieties to determine the variety identity of a sample and to detect mixtures of varieties.

RESULTS

Table 1 summarises the number of informative SNPs for each of the 34 varieties, within the set of 33 reported SNPs and, for each variety, the number of the other varieties against which discriminating SNPs exist.

All varieties have informative SNP loci amongst the set of 33 SNPs, but some varieties (e.g. Barque, Cowabbie, Fitzroy, Grout and Lockyer) are more limited.

Eighteen of the varieties have at least one discriminating SNP against all other 33 varieties. Only two varieties have three or more discriminating SNPs against all other varieties.

Table 1 **Number of informative SNPs for each of 34 barley varieties within the set of 33 reported SNPs and the number of the other varieties against which discriminating SNPs exist**

Variety	Informative SNPs	No of other varieties for which discriminating SNPs (DSNP) exist			
		> 0 DSNP	> 1 DSNP	> 2 DSNP	> 3 DSNP
Barque	10	23	13	6	1
Baudin	29	32	31	31	25
Buloke	26	31	30	28	25
Capstan	26	32	30	27	23
Cowabbie	14	30	21	13	6
Dhow	31	32	32	30	30
Doolup	33	33	32	31	31
Fitzgerald	23	33	33	31	29
Fitzroy	17	33	29	26	17
Flagship	29	33	32	32	30
Fleet	30	32	31	29	27
Franklin	32	33	33	32	31
Gairdner	25	33	32	27	25
Galleon	30	32	31	30	26
Grimmett	22	33	32	30	26
Grout	17	31	25	21	15
Hamelin	29	32	31	28	26
Hannan	32	33	33	32	29
Keel	32	32	31	28	26
Lockyer	17	33	31	27	22
Lofty Nijo	26	33	32	28	27
Mackay	30	32	32	30	29
Maritime	30	33	31	31	30
Molloy	31	33	33	33	31
Mundah	28	33	32	31	29
Roe	17	28	24	15	6
Schooner	25	31	29	23	18
Sloop	32	33	31	28	26
Sloop SA	27	32	30	25	23
Sloop VIC	27	33	32	31	27
Stirling	33	33	30	27	24
Tantangara	25	32	29	29	28
Urambie	31	33	33	33	33
Vlamingh	16	33	29	21	13

CONCLUSION

The results demonstrate that it should be possible to develop a cost effective method, by applying SNP based technology to composite samples, to determine the varietal identity of barley varieties. Further work is required to evaluate more SNPs and identify a suite that will provide better discrimination amongst barley varieties. Further work is also required to develop profiles for varieties of interest, not included in the set reported here. To achieve reliable discrimination between varieties, it is considered that at least three discriminating SNPs for any variety pair would be desirable.

Preliminary evaluation of the proving trial would indicate that the methodology is effective in identifying varieties provided by the collaborators. However, as was anticipated, there have been some relatively minor issues associated with discrepancies between different sources of the same varieties. If such a system is adopted by the industry, these issues will not be on-going as they are a function of retrospectively fitting a highly discriminating technology to an older less discriminating system. Also as expected, differentiation has been limited in some cases by the present lack of discriminating SNPs.

Reliable identification of contaminants is not possible at present. Data from the proving trial indicates that this will require more optimisation if a meaningful assessment of varietal purity around the commercial 95% level is to be achieved.

The results to date indicate that, with the implementation of a more extensive suite of SNPs, it will be possible to implement a reliable qualitative test that will indicate the identity of the major variety present in a sample. Such a test would be expected to also be able to identify major contaminants at levels greater than 10%. While this will not be the test ultimately desired by the industry, it would address the likely major sources of contamination of grain deliveries and assist the barley industry in meeting its contract trade obligations and could be considered as an interim measure, while further optimisation of the technology is undertaken to provide reliable estimates of contamination at critical trade levels. Such a test is likely to be able to be offered at a cost of approximately $60–70 (excl. GST).

SNPs occur in all species and there is no reason why the technology, once established in barley could not be readily transferable to other crop species, provided suitable SNPs have been identified and are available.

KEY WORDS

variety Identification, single nucleotide polymorphism, DNA fingerprinting

Paper reviewed by: Dr Chengdao Li

Forecast disease resistance profile for the Western Australian barley crop over the next three years

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KEY MESSAGES

There is likely to be a shift in the disease resistance profile of the Western Australian barley crop with the adoption of newer high yielding malt and feed barley varieties in the next three years. This paper outlines what the disease profile of the state's barley crop may look like up to the release of new malting barley varieties in three years time.

AIMS

To stimulate discussion on what could be the immediate short term disease scenarios in the Western Australian barley industry due to the adoption of new barley varieties now on offer.

BACKGROUND

Last year an edition of 'Landmark' the Journal of the NIAB Association of the UK highlighted the situation faced by Scottish wheat growers in 2007 with a brown rust epidemic (Bayles 2008). Normally brown rust is a rarity in the northern areas of the UK. Seasonal circumstances in 2007 unfortunately favoured its development. The article inferred that breeding for disease resistance can be ineffective where seasonal circumstances favour a disease of low priority that becomes a major cause of crop loss as a result. In the UK example the focus had been on breeding resistance for yellow rust at the expense of developing useful brown rust resistance.

This NIAB article prompted an examination of the current disease resistance profile of the barley crop in Western Australia. The examination included predictions of the disease resistance profile in three years time. These predictions assumed a certain level of adoption of the new varieties now available either accredited for malting or released as feed. Among these varieties there is enhanced disease resistance to one or a number of the common diseases that pose a risk to the WA barley crop.

METHOD

The area planted to the current barley varieties grown in Western Australia was obtained from industry estimates gathered in 2007 and 2008 (Table 1). These areas were then converted into a percentage of the total area devoted to barley in that season. While most of the newly released varieties do not feature significantly in this data yet, Vlamingh has seen a dramatic adoption of planting in 2008 to account for 10% of the barley area.

Based on the most recent data available from DAFWA's Pathology Group (Russell et al. 2008), disease scores for the 6 most prominent leaf diseases and CCN were attributed to each variety (Table 2). For older varieties reference was made to the Crop Variety Sowing Guides (CVSG) of 2005 (Garlinge 2005) and 1989 (Brown 1999) to complete missing data. These are designated with lower case letters in Table 2. Disease scores were rated on an 'alpha' scale of 6 degrees of severity of VS (very susceptible), S (susceptible), MS (moderately susceptible), I (intermediate), MR (moderately resistant) and R (resistant). Any ES (extremely susceptible) ratings were grouped with the VS rating. Varieties were rated as either S or R to CCN. CCN resistance ratings have not been assessed for a number of new varieties (Table 2).

The total area of all the varieties with the same disease rating for each of six diseases was then calculated. A profile was determined for each disease using these values as a percentage of total barley area, based on the 2007 and 2008 figures (Figures 1 to 6).

Table 1 **Percentage area of barley varieties in Western Australia in 2007 and 2008, including estimates for the 2011 season**

Barley segregation	Variety	2007 Area planted %	2008 Area planted %	2011 % (Forecast)
Malt	BAUDIN	24.35	22.01	18
	BULOKE	0.29	2.44	30
	FLAGSHIP	0.00	0.04	0.5
	GAIRDNER	21.42	18.70	10
	HAMELIN	11.53	10.13	9
	SCHOONER	0.53	0.17	0
	STIRLING	16.65	10.28	5
	VLAMINGH	0.30	10.44	13
Feed	BARQUE	0.56	1.25	1
	BEECHER	0.08	0.08	
	CAPSTAN	0.14	0.18	
	CHEBEC	0.01		
	DASH	0.96	1.68	1.5
	DOOLUP	0.15	0.11	
	FITZGERALD	0.79	0.51	
	FLEET		0.11	1
	HANNAN		0.00	1
	HARRINGTON	0.10		
	HINDMARSH		0.02	4
	KEEL	0.36	0.18	
	KETCH	0.01		
	LOCKYER		0.02	1
	MARITIME		0.02	
	MOLLOY	0.81	0.72	
	MOONDYNE	0.00	0.01	
	MORRELL	0.00		
	MUNDAH	15.43	15.35	2
	OCONNOR	0.38	0.21	
	ONSLOW	0.15	0.16	
	ROE		0.02	1
	SKIFF	0.29	0.21	
	SLOOP	0.05	0.04	
	UNICORN	0.07	0.07	
	URAMBIE		0.00	
	YAGAN	4.54	4.63	2
	YARRA	0.06	0.19	
Total malt		**75.08**	**74.21**	**85.5**
Total feed		**24.92**	**25.79**	**14.5**
TOTAL		**100**	**100**	**100**

The percentage area of barley varieties in Western Australia in three years time (2011) was estimated. This estimate is subjective and open to further debate. The proportion of malt varieties is expected to increase in the future due to the high yielding accredited malt variety Buloke exhibiting yields that are competitive with feed varieties. Disease profiles were calculated using the 2011 estimates Figures 1 to 6 depict the difference in disease profile between recent seasons and 2011, based on the estimates of variety plantings for 2011.

Table 2 **Disease rating of barley varieties from DAFWA plant pathology group (upper case) and older ratings from 1989 and 2005 Crop Variety Sowing Guides (lower case)**

Barley segregation	Variety	Scald	Net type—net blotch	Spot type—net blotch	Mildew	BYDV	Barley leaf rust	CCN
Malt	BAUDIN	I	S	S	S	MR	S	S
	BULOKE	MS	MS	MS	MR	MS*p*	S	S
	FLAGSHIP	MS/I	I	I	MS	I*p*	S	R
	GAIRDNER	I	I	S	MS	R	S	S
	HAMELIN	S	S	S	S	VS	S	S
	SCHOONER	MS	I	I	S	MS*p*	MS*p*	S
	STIRLING	S	S	S/MS	S	I	S	S
	VLAMINGH	MR	I	S	S	MS	MS	S
Feed	BARQUE	MR	S	I	R	I	S	R
	BEECHER	s	s	s	s	es	sp	
	CAPSTAN	I	MS	I	I	S	MS	R
	CHEBEC	*	*	*	*	*	*	*
	DASH	R	I	S	R	S	R	R
	DOOLUP	VS	S	S	S	I	S	R
	FITZGERALD	mr	I	MS	I	MR	S*p*	
	FLEET	MS	S	S	I	Ip	R	R
	HANNAN	MR	S	S	MS	S*p*	S	
	HARRINGTON	s	MS	I	I	I*p*	S*p*	
	HINDMARSH	MR	MS	S	MR	MS*p*	S	R
	KEEL	mr	r	mr	s/mr		vs	
	KETCH	*	*	*	*	*	*	*
	LOCKYER	I	I	S	MS	S*p*	S	
	MARITIME	I*p*	MS*p*	S*p*	S	S	-	R
	MOLLOY	S	S	MS	MS	I*p*	S	S
	MOONDYNE	ms	MR	I	I*p*	MR	R*p*	
	MORRELL	mr	mr	ms	r	i		
	MUNDAH	S	MS	MS	S	MS*p*	S	S
	OCONNOR	ms	I	MS	S	VS	S*p*	
	ONSLOW	s	MR	I	S	I	MS*p*	
	ROE	S/MS	MS	I	I	S*p*	S	
	SKIFF	s	R	S	I	I	S*p*	
	SLOOP	s*p*			i*p*		vs*p*	
	UNICORN	vs*p*	i*p*	ms	mr*p*	mr	s*p*	
	URAMBIE	r	r	vs	ms		s	
	YAGAN	ES	I	S	MS	S	S	
	YARRA	S	MS	S	S	S	S*p*	R

Capital letters = ratings from DAFWA Plant Pathology Project 2007. *p* = provisional.

Lower case = ratings from other sources, i.e. CVSG 2005, eastern states variety guides. * = No information available.

The varieties Hannan and Hindmarsh are listed as feed for the purpose of this exercise. These varieties may become accredited malt varieties in future. Any changes will be announced by the commencement of the 2010 season for Hannan and 2011 for Hindmarsh. Any changes shouldn't influence the area of each of these varieties. Hannan would be suitable for a small domestic market that is likely to be managed by planting contracts. If Hindmarsh became accredited for malting any effect on area of this variety wouldn't be expected until after 2011. The same applies for any new elite malting lines currently being tested for malt accreditation (i.e. WABAR 2315).

RESULTS

With the exception of BYDV (Figure 1) and to a lesser degree, Net type-net blotch (Figure 2), the disease resistance profile of the barley crop in Western Australia appear to strengthen slightly based on estimates of variety composition in 2011.

Barley Yellow Dwarf Virus (BYDV)

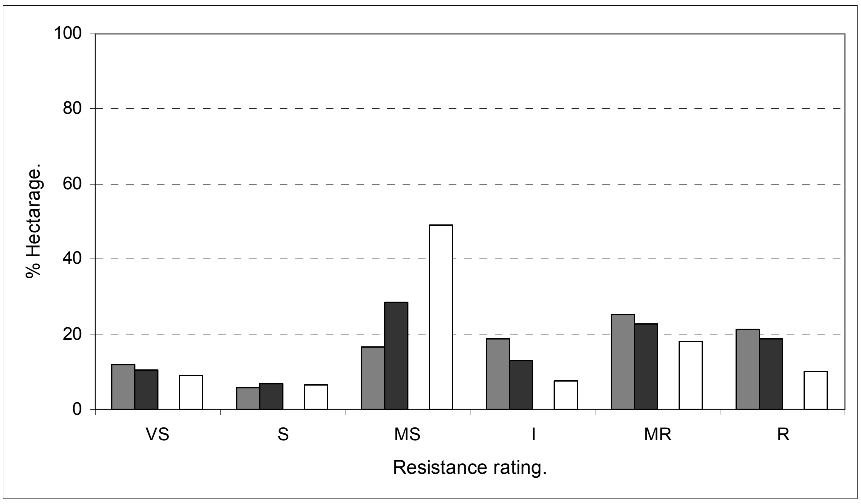

Figure 1 Disease profile for barley in Western Australia for barley yellow dwarf virus (BYDV) as of 2007 (▒), 2008 (█) and projected for 2011 (□).

Net type—net blotch

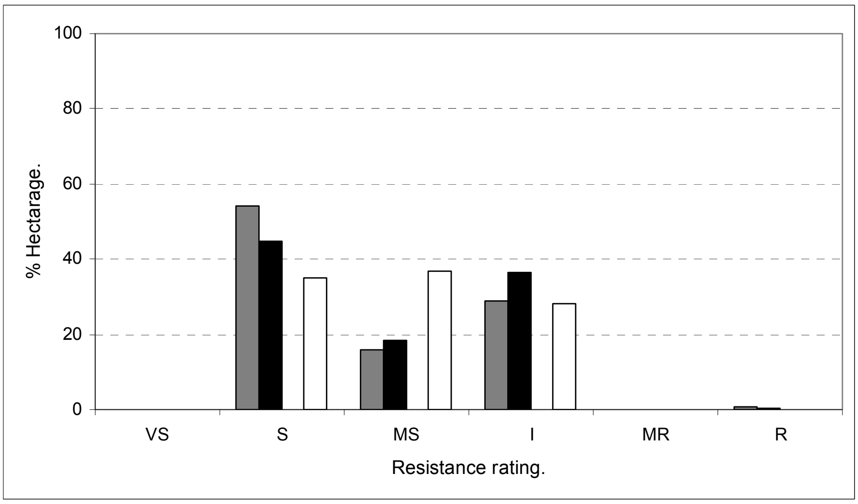

Figure 2. Disease profile for barley in Western Australia for Net type—net blotch as of 2007 (▒), 2008 (█) and projected for 2011 (□).

Figures 1 and 2 indicate a decrease in the area planted to I and/or MR and R rated varieties for BYDV and Net type-net blotch. The levels of resistance to Spot type-net blotch (Figure 3) and Barley leaf rust (Figure 4) may not change appreciably in the next six seasons. In contrast there is a clear increase in the proportion of the crop rated moderately resistant to powdery mildew (Figure 5) and to a lesser degree scald (Figure 6).

Spot type—net blotch

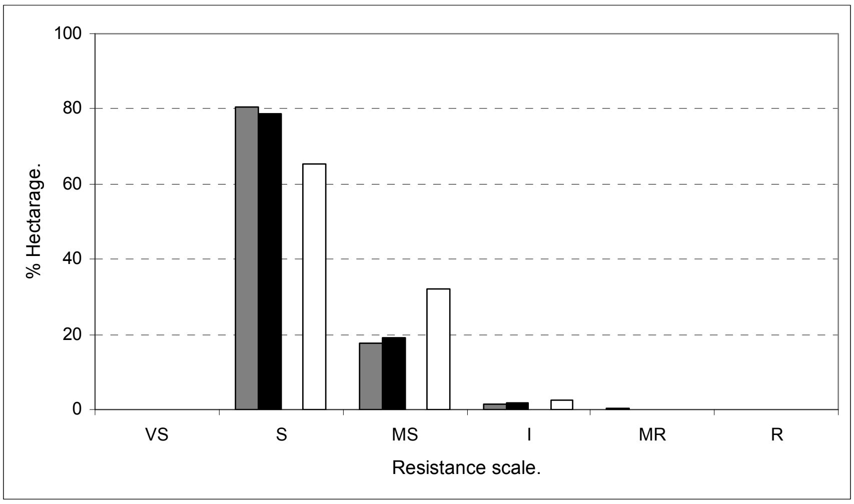

Figure 3 Disease profile for barley in Western Australia for Spot type—net blotch as of 2007 (▮), 2008 (▮) and projected for 2011 (□).

Barley leaf rust

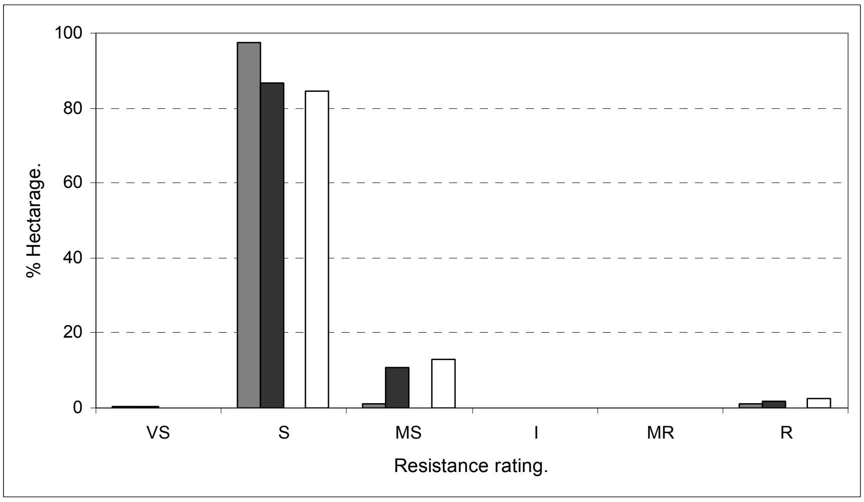

Figure 4 Disease profile for barley in Western Australia for barley leaf rust as of 2007 (▮), 2008 (▮) and projected for 2011 (□).

Powdery mildew

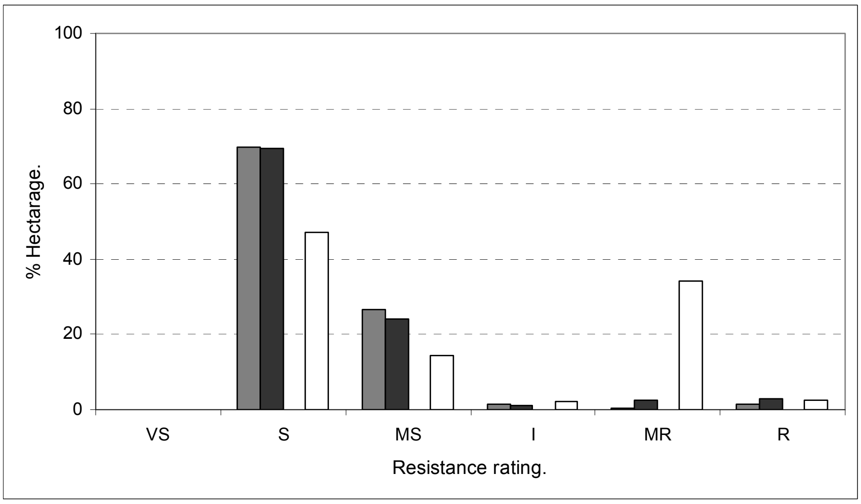

Figure 5 Disease profile for barley in Western Australia for powdery mildew as of 2007 (▒), 2008 (█) and projected for 2011 (□).

Scald

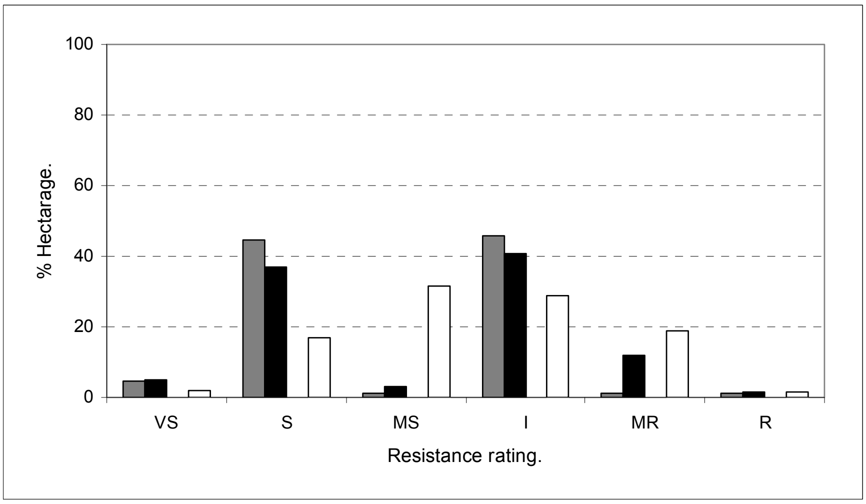

Figure 6 Disease profile for barley in Western Australia for scald as of 2007 (▒), 2008 (█) and projected for 2011 (□).

A resistance level of intermediate or better can be considered as the minimum level to be useful for impacting on the requirement for disease management intervention (i.e. reducing the requirement for fungicide applications). Table 3 shows the projected change in this group of resistance levels, highlighting the expected improvement in the levels of powdery mildew resistance. While there is a projected improvement in resistance to Spot type-net blotch and BLR, the overall proportion of varieties with poor levels of resistance is expected to be high. A clear reduction in overall resistance to BYDV and Net type-net blotch is also projected, while overall resistance to scald may decrease slightly.

Table 3 **Proportion (%) of the Western Australian barley crop with a resistance rating of 'I' or better in 2007, 2008 and estimated for 2011**

Disease	2007	2008	2011
Barley leaf rust	1.0	1.8	2.5
BYDV	65.3	54.2	35.5
Net type-net blotch	29.8	37.0	28.0
Powdery Mildew	3.3	6.7	38.5
Scald	48.1	54.4	49.5
Spot type-net blotch	1.8	2.0	2.5

DISCUSSION

Based on the results it could be suggested that a general improvement, though slight, in the overall disease resistance profile of the barley crop in Western Australia can be expected in the next three seasons.

A notable improvement can be seen in the projected disease profile for powdery mildew which is a significant problem in the high–medium rainfall areas. This improvement can be attributed to the projected adoption of Buloke, which has superior powdery mildew resistance amongst the other malting varieties. It is expected that Buloke will replace the feed variety Mundah to some extent which will contribute to this improvement. This will come at the cost of resistance levels to other diseases. Buloke is likely to displace Gairdner and Baudin which both have superior resistance to scald, and BYDV and Gairdner also has superior net type-net blotch resistance.

Table 3 indicates a very subtle, if any, improvement in overall resistance to barley leaf rust and Spot type-net blotch in 2011. The increased susceptibility of the crop to BYDV is also highlighted. This is mainly brought about by the anticipated decline in the area of Baudin and Gairdner. Another consideration is the areas where susceptible varieties are likely to be more prominent. For example Vlamingh has had an influence on the projected decrease in resistance to BYDV in this exercise. Vlamingh and Buloke are more likely to be grown in the western medium to high rainfall environments which are more suited to BYDV development. This could lead to an increased requirement to mitigate the risk from this disease in these areas.

Despite a slight improvement in projected levels of resistance to barley leaf rust well over 80% of the area still likely to be sown to susceptible varieties in three years time (Figure 4 and Table 3). This disease may be the greatest threat to the state's barley crop, especially on the south coast and adjoining districts.

The profile for scald shows a more even spread of the disease resistance within the crop by 2011 (Figure 7). While there is no net increase in varieties rated intermediate or better the proportion of the crop moderately susceptible or better is projected to improve. Buloke and Flagship are likely to exacerbate this disease threat in medium rainfall environments because of their susceptibility.

There is a suggestion that the increased area sown to Buloke may contribute to decreased powdery mildew disease pressure in susceptible crops such as Baudin. These sort of influences are not well understood.

While this exercise indicates lower vulnerability to some barley diseases in coming seasons growers will still be required to maintain a vigilant approach to disease management. The results suggest that more emphasis on barley leaf rust, BYDV and scald may be required in coming seasons.

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KEY WORDS

barley, malt, feed, disease, resistance, pathology

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Malting barley varieties differ in their flowering date and their response to changes in sowing date

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KEY MESSAGES

- The correct choice of sowing date for different barley varieties is the key to maximising yield potential.
- Understanding a barley variety's flowering date assists in the development of agronomic and risk management packages for advisors and growers.

AIMS

With so many new malting varieties available for sowing, there is some confusion as to what varieties are actually early flowering like Stirling and what varieties are actually later flowering than Stirling. This paper aims to provide the latest guides for agronomists and consultants to advise their clients on variety choice.

BACKGROUND

Development or time to flower in barley is controlled by temperature and daylength. Barley is known as a 'long day' plant, as its development is often inhibited under shorter days (daylength less than 16 h). Varieties grown in Western Australia differ in their response to sowing date because of differences in the duration of their basic vegetative phase (BVP) and their daylength length sensitivity (DLS).

Basic vegetative period (BVP)—Is the minimum number of leaves formed on the mainstem when a plant has had its vernalisation response satisfied and is grown in a daylength above 16 h. BVP modifies the plant's response to temperature and daylength. As our daylength never exceeds 16 h in Western Australia, we measure the BVP of barley varieties by growing them with supplementary lighting.

Daylength sensitivity (DLS)—DLS is a measure of the sensitivity of a variety to daylength and reflects the responsiveness of a variety to a change in sowing date. DLS is the difference in duration to awn emergence between plants grown with and without supplementary lighting. DLS insensitive varieties will form the same number of leaves on the mainstem, regardless of sowing date. The final leaf number on DLS sensitive varieties, however, will differ due to sowing date.

Vernalisation response (VRN)—VRN is a measure of the responsiveness of a variety to a certain number of 'cold' hours needed to initiates it development. All barley varieties currently grown in Western Australia are spring types and as such have little or no vernalisation requirement, although varieties such as Ulandra from New South Wales have a mild vernalisation requirement.

DISCUSSION

Stirling has been the dominant barley in Western Australia for nearly 25 years. One of the reasons for this varieties adaptation to most locations and sowing dates is because it has short BVP and a high DLS (Table 1). Varieties with medium BVP and moderate DLS (i.e. Buloke, Flagship and Gairdner) or with long BVP and mild DLS (i.e. Franklin) are better suited to earlier sowing opportunities than Stirling. However. they are often less suited to later sowing opportunities as there is a risk of flowering too late. Varieties with short BVP and very high DLS (i.e. Baudin and Skiff) are adapted to both early and late sowing dates. Therefore in order to understand how a variety may respond to changes in sowing date or when it may flower at a given sowing date relative to another variety, it is important to know the BVP and DLS of the varieties concerned. The BVP and DLS ratings of current malting varieties and the feed variety Mundah are listed in Table 1.

Table 1 **BVP and DLS responses of current malting barley varieties and the feed variety Mundah and their relative maturity ratings (from Farmnote 312)**

Variety	Basic vegetative phase (BVP) rating	Daylength sensitivity (DLS) rating	Maturity rating
Baudin	Short	Very high	Medium
Buloke	Medium	Medium	Medium
Flagship	Medium	Medium	Medium
Gairdner	Medium–Long	Medium	Medium
Hamelin	Short	High	Early
Schooner	Short–Medium	Medium	Medium
Stirling	Short	High	Early
Vlamingh	Short–Medium	High	Medium
Mundah	Short–Medium	Low	Very early

The duration to awn emergence is a reliable way of representing differences between varieties in flowering date. Baudin, Buloke, Flagship, Gairdner and Vlamingh are classed as medium spring maturity varieties based on their duration to awn emergence from a late May to early June sowing.

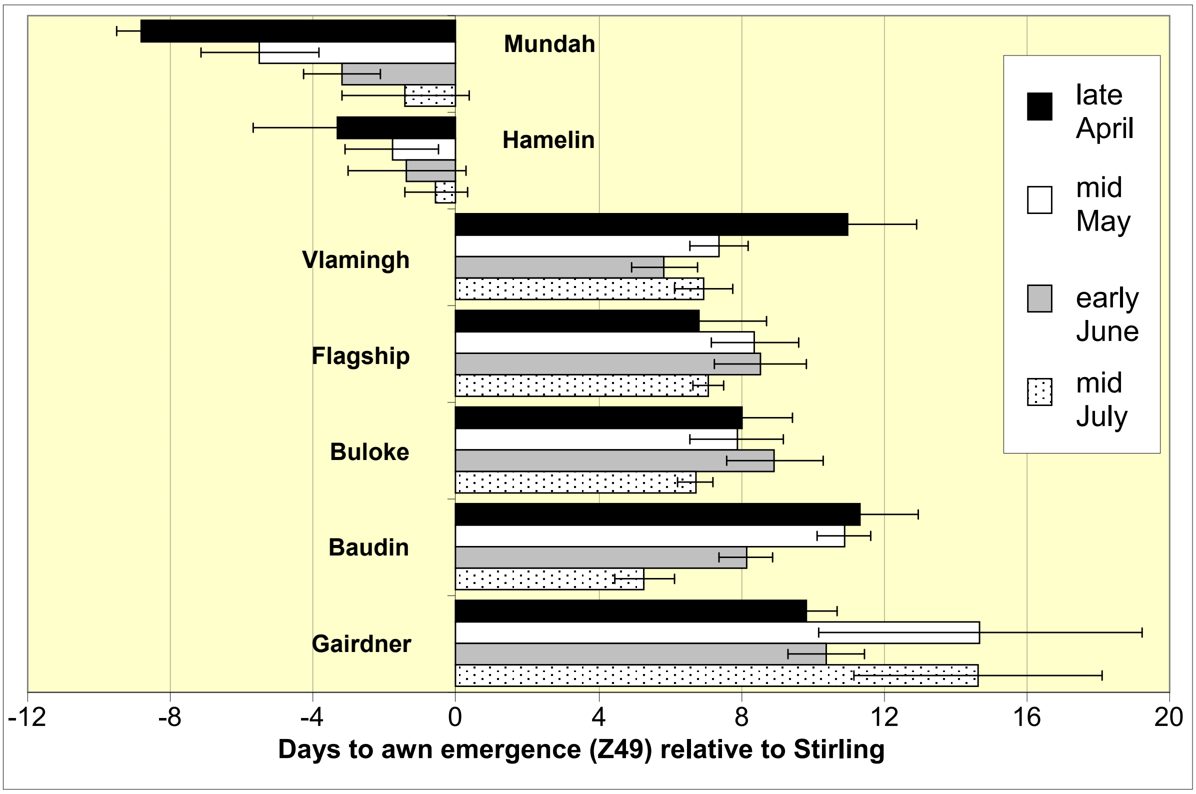

Figure 1 Average difference (± se) in duration to awn emergence (days) between Stirling and Mundah, Hamelin, Flagship, Buloke, Baudin and Gairdner when sown in either late April, mid May, early June and mid July. [Note: This is a composite analysis of flowering date data from three locations—Northam, Katanning and Esperance—and different seasons.]

The factors that control the flowering date response of Baudin, Buloke, Flagship, Gairdner and Vlamingh differ (Table 1) and this influences how they respond to changes in sowing date (Figures 1 and 2). Figure 1 shows the difference in their duration to awn emergence between all the varieties depicted in Table 1 relative to Stirling, excluding Schooner. Figure 2 shows how the time to awn emergence from sowing decreases with delays in sowing date.

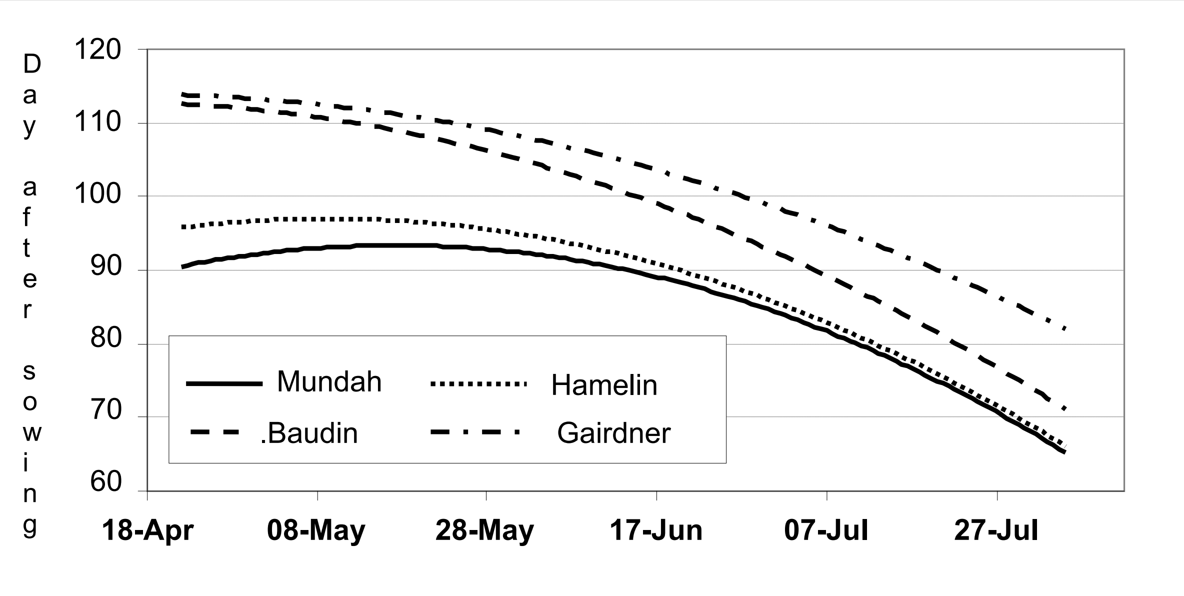

Figure 2 Days after sowing to reach awn emergence for four varieties differing in BVP and DLS (Mundah, Hamelin, Baudin and Gairdner) for sowing from late April to late July. [Note: This is a composite analysis of flowering date data from three locations—Northam, Katanning and Esperance—and different seasons.]

VARIETY NOTES

Buloke: Buloke is a medium spring variety.

Buloke reaches awn emergence earlier than Gairdner at all sowing dates and is up to three days earlier to awn emergence than Baudin with early May, late May and early June sowing. Buloke may be slightly later flowering than Baudin with July sowing as Baudin's development pattern is highly sensitive to daylength. If Buloke and Baudin were sown in summer, Baudin would flower earlier than Buloke, as Buloke has a longer BVP.

Buloke is always later flowering than Hamelin, Mundah and Stirling. Buloke reaches awn emergence some 8–10 days later than Hamelin and 6–8 days later than Stirling, depending on sowing date.

Baudin: Baudin is a medium spring variety.

Baudin's development pattern is based on a short BVP and a very high DLS. Baudin is generally a couple of days earlier to awn emergence than Gairdner at all sowing dates during winter, but the differences between Baudin and Gairdner increase as seeding is delayed.

Baudin may reach awn emergence at the same time as Stirling or later depending on when it is sown. When sown in summer Baudin flowers at a similar time to Stirling. When sown in winter the development pattern of Baudin is delayed because of sensitivity to daylength. As seeding is delayed, awn emergence differences between Stirling and Baudin decrease from 10–12 days in April to 4–6 days in July.

Flagship: Flagship is a medium spring variety.

The developmental pattern of Flagship is similar to that of Buloke and both will reach awn emergence within a couple of days of each other at all sowing dates.

Flagship is always later flowering than Hamelin, Mundah and Stirling. Flagship reaches awn emergence some 8–10 days later than Hamelin and 6–8 days later than Stirling, depending on sowing date.

Gairdner: Gairdner is a medium spring variety.

Gairdner has the longest period between sowing and awn emergence of all current malting varieties and will form at 10–13 leaves on the mainstem before it will flower. With May sowing Gairdner may be up to 6 days later than Buloke, Baudin, Flagship and Vlamingh.

Gairdner is always later to awn emergence than Hamelin, Mundah and Stirling, regardless of sowing date. Gairdner reaches awn emergence some 10–14 days later than Hamelin and 8–12 days later than Stirling, depending on sowing date.

Hamelin: Hamelin is an early spring variety.

Hamelin has a development pattern which is similar to that of Stirling. That is, short BVP and high DLS. Hamelin reaches awn emergence up to four days earlier than Stirling depending on sowing date, with differences between the varieties decreasing as seeding is delayed from April to July.

Stirling: Stirling is an early spring variety

Stirling has a development pattern which is well suited to the Western Australian environment. It has a short BVP and a high DLS. Stirling will flower with as few as 6 leaves on the mainstem when grown over summer, but may have up to 12 leaves when it flowers with winter sowing.

Vlamingh: Vlamingh is a medium spring variety.

The development pattern of Vlamingh is slightly different to that of Buloke and Flagship, having a short to medium BVP and a high DLS compared to the medium BVP and DLS of Buloke and Flagship. It reaches awn emergence later than Buloke and Flagship with April sowing but within a couple of days of Buloke with mid May to July sowing. Vlamingh reaches awn emergence at a similar time to Baudin with April sowing, but is slightly earlier with May and June sowing.

Vlamingh is later to awn emergence than Hamelin, Mundah and Stirling. Vlamingh reaches awn emergence some 8–12 days later than Hamelin and 6–10 days later than Stirling depending on sowing date.

KEY WORDS

barley, malt, feed, varieties, maturity, flowering date, Western Australia

ACKNOWLEDGMENTS

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Paper reviewed by: Ron McTaggart

Market development for new barley varieties

Linda Price, Barley Australia

The decision for a maltster or brewer to take on a new ingredient (i.e. raw malting barley or processed malt different to what they have been regularly purchasing) in their manufacturing business is an extremely serious decision.

From a brewer or a maltster's perspective, terms like consistency, reliability, performance, known characteristics, predictability, and varietal understanding are key to their requirements from malting barley or processed malt.

Malting barley, to a maltster, is at the very core of their business—the confidence and understanding they have of the malting barley variety is one of their main business ingredients. Although the malting process is a scientific one, familiarity with the variety to the maltster is key to getting the most out of the variety in terms of performance.

Maltsters (like growers) are chasing yield—they want to purchase 1000 t of barley and sell as close to 1000 tonnes of malt as possible. A maltster's ability to 'read' the variety to make it perform to its optimum is a lot due to the maltster's familiarity with the variety and all its nuances.

Maltsters need significant reasons to change varieties of malting barley as change represents risk—risk that can be beneficial to their business as well. Malting, like farming, is a business with large overheads and small margins and every post must be a winner in a successful malting company.

The quality of the malt produced must be appealing to the customer, the brewer. Consistency of quality is integral to the appeal. The malt must meet the brewer's set of specifications in terms of its quality performance in the brewhouse; as with the maltster, the brewer is chasing yield and when the brewer buys 100 tonnes of malt he wants to make as many hectolitres of beer as possible. The term for quantifying this is extract. Extract is a key parameter that Australia's barley breeders are continually seeking to improve.

[NB: 1 tonne of malting barley yields around 70 hectolitres of beer, depending on recipe, etc. a hectolitre is equal to 100 litres.]

Australian maltsters all service two distinct markets—the local brewing market (predominantly sugar adjunct or pure malt brewing) and the international brewing market (predominantly a starch adjunct market). There are a few exceptions to this rule of thumb in market needs.

The international brewing market is either one or two degrees away from the Australian barley farmer. Farmers either sell raw malting barley via grain marketers to overseas maltsters (who make the malt and then sell this malt to local brewers); or the farmers sell (either direct or via grain marketers) to Australian maltsters and the Australian malting companies sell processed malt (almost 800 000 tonnes/year) to overseas brewers.

Many brewers operate in highly sophisticated, computerised production factories and require malt of consistent supply, reliable performance and quality, and malt that the brewer is comfortable using.

Many breweries make beer in batch sizes of hundreds of hectolitres using significant amounts of raw ingredient, and it is vital to the business (as in any business) that the product is made successfully.

Depending on the brew being made, the brewer will issue a list of specifications to the maltster detailing quality parameter requirements like fermentability, total nitrogen (aka protein in barley), diastatic power, Kolbach, wort viscosity, wort colour, etc.

The quality parameters of the malt (derived from the inherent quality characteristics in the specific variety of malting barley) are vital to the brewer from a production and profitability perspective. The brewer over time has no doubt become used to certain malt blends made from specific varieties and will seek to use them again as they deliver the result required.

It is therefore unlikely a brewer would ever request a new and unknown variety because of risk—financial and production risk in dealing with an unknown barley variety. The impetus for varietal change would either come from the maltster or the grain marketer.

Many breweries around the world have their own brewery-specific list of varieties they accept and it can take up to a year for brewers to be satisfied with their own evaluation of the performance of the new malt.

When a new malting barley variety is released to Australian barley farmers there is a vital balancing act to be managed to step production with market demand for the new variety.

On release of a new variety, it will have been through many years (8+) of micro and commercial scale trials in Australia to determine its suitability as a malting and brewing variety. The commercial scale trials are conducted through the industry-endorsed Varietal Accreditation process driven by Barley Australia, the Malting and Brewing Industry Barley Technical Committee (MBIBTC) and the GRDC/industry-sponsored Pilot Brewing Australia. From this data, all maltsters and brewers in Australia are able to see the barley perform in commercial and micro-scale tests.

Simultaneously, grain marketers and maltsters are beginning to discuss the new lines with their customers overseas. When accreditation in Australia is achieved, and supply is increasing (as bulk-up and adoption commences by the farmers) small parcels of the variety are sent to the potential purchasers for the purchaser's own trials in their factories.

In initial stages this could be as little as 1 kg, as brewers and maltsters look to make purchasing decisions. Slowly, evaluation for individual companies takes place and for brewers this can take up to six months for a full evaluation of one batch as shelf life of the beer (termed 'stability') is a key parameter.

Often the trial batches are done in conjunction with the malting or marketing company sending a technical representative to help the customer through the malting or brewing process and explain the benefits of the new variety.

For the Australian barley industry players, considerable time and effort is expended by individual companies in order to launch the new varieties in to the marketplace overseas.

It is for this reason that the importance of Barley Australia, MBIBTC and Pilot Brewing Australia is increasing. As we move into the deregulated environment industry-good bodies take on an increasingly important role in the market development for new varieties. It is important for all the industry that there are congruent messages regarding each variety and also that there is some generic promotion of the new variety to the international marketplace.

The de-regulated marketplace for barley does raise the level of difficulty in getting new varieties to the market. There is requirement for increased levels of coordination and communication between growers and marketers, maltsters and brewers.

The stepping of growers' barley production with market demand is critical to not only price structure but price sustainability in the longer term. It is important to remember that the world international malting barley trade is only around 4 million tonnes and when one considers Australia's market share (between 40 and 65%) and the number of varieties on offer from all over the world there is not a lot of margin for error.

A coordinated approach is the way forward for successfully growing new varieties in to the market—this involves grower engagement with their marketers and maltsters, involvement in the regional barley councils and an increased awareness requirement for what the market requires in malting barley varieties.

A new malting barley variety, no matter how agronomically spectacular, needs to be carefully placed into farm rotations with a mind that market share of any variety takes time to grow.

Price relativity will always reflect the demand for a variety but it is important to remember that a variety emerging on to the market may be priced lower than existing varieties while the market establishes where it sits in relation to other varieties for quality demand and value.

Understanding the nature of the international malting and brewing market helps to explain the need for moderate introduction and adoption of new varieties for malting barley, and careful industry stewardship from the relevant industry groups help to manage this function.

Response of wheat varieties to sowing time at Mt Barker, Katanning and Newdegate in 2008

Brenda Shackley and **Vicki Scanlan**, Department of Agriculture and Food, Western Australia, Katanning

KEY MESSAGES

- In general frost and late rains in 2008 favoured the yields of the longer maturing varieties, particularly at the Katanning site.
- Magenta dominated the yield results across the three regions while Wyalkatchem's performance was extremely variable and well below the performance of many other varieties.
- Preliminary falling number results indicate large differences between varieties at Mt Barker, ranging from extremely poor sprouting tolerance to moderately poor sprouting tolerance.
- Grain quality results were not available at time of printing.

AIMS

To investigate the performance of new wheat varieties at different times of sowing. To identify any specific risks associated with new varieties in the southern agricultural region of WA.

METHOD

Field based trials were located on duplex soils at the Mt Barker Research Station, the Great Southern Agriculture Research Institute in Katanning and the Newdegate Research Station in 2008. The trials included 24 wheat varieties from various Australian breeding programs, at three sowing times. There was a huge range in sowing times reflecting the different seasons experienced at Mt Barker, Katanning and Newdegate. The sowing dates were 16 May, 30 May and 13 June at Mt Barker; 6 May, 23 May and 16 June at Katanning and 16 May, 4 June and 26 June at Newdegate.

RESULTS AND CONCLUSION

Season

The 2008 season was extremely variable with good to patchy starts around the regions, a wet July then a dry August, frost, and then good end of season rainfall which then continued into harvest leading to sprouted grain in some areas.

The growing season rainfall was 382 mm at Mt Barker, 306 mm at Katanning and 349 mm at the Newdegate. Rainfall at the end of October was 71 mm at Mt Barker, 45 mm at Katanning and 90 mm at Newdegate. Mt Barker then received 166 mm in November and 26 mm in December, while Katanning had 26 mm and 20 mm respectively. Newdegate had 36 mm in November and 63 mm in December.

Grain yield

Time of sowing did not result in significant differences in overall grain yields at any of the sites, which is attributable to the wet finish to the season. The average grain yields across times of sowing ranged from just over 4 t/ha at Mt Barker to 2.6 t/ha at Katanning and 2.5 t/ha at Newdegate. In comparison there was a significant interaction between time of sowing and variety, with frost and late rains playing a major role in how the varieties responded when sown at a particular date.

The performance of Wyalkatchem in 2008 was extremely variable—frost damage being the main cause at Katanning and to a lesser extent at Newdegate. In turn, Magenta (released in 2007) was either the highest yielding variety or not statistically distinct from the highest yielding variety. The exception was at the first sowing time at Katanning, which suffered severely from head frost damage (Table 1). Magenta is not recommended in Agzone 6 due to low sprouting tolerance, similar to Wyalkatchem. The full data set of falling numbers was not available at the time of printing but will be reported in future.

The long season soft wheat EGA Jitarning also performed well in 2008—receiving less frost damage and able to utilise the late rains in 2008. The newly released APW Endure (IGW2784), which is the longest maturing Intergrain variety, was also able to ‘escape’ major frost damage at the Katanning site along with Calingiri (Table 1).

Seven new wheat varieties Espada (APW), Mace (APW), Fang (APW), Endure (APW), Fortune (ASWN), Zippy (APW) and Bumper (ASW) were released in 2008 targeting Western Australian growers. The early maturing variety Zippy was the lowest yielding at Katanning and Newdegate, even at the later sowing dates. The early maturity of this variety was unlikely to be an advantage with the wet finish experienced in the 2008 season. Time will tell if this variety has an advantage over others with later sowing and a drier finish. Fortune yields were similar to Calingiri and superior to the shorter season noodle varieties Binnu and Yandanooka (and Arrino at Newdegate). Mace exhibited superior yields compared to Wyalkatchem at the early times of sowing at all sites. Espada and Fang also exhibited impressive yields at various times of sowing across the sites. Bumper was not included at any of the three sites.

Long term yield data from National Variety Testing (NVT) for the period 2000 to 2007 indicate that while Wyalkatchem is one of the highest yielding varieties the recently released varieties Espada and Magenta have comparable long term yields (please refer to the Wheat Variety Guide 2009 Western Australia). Other varieties such as Fang and Young are competitive with Wyalkatchem in various Agzones. Overall the soft wheat Bullaring is the highest yielding named variety tested in the NVT system.

Preliminary sprouting results

Low falling number or poor sprouting tolerance was one of the major issues in 2008. Preliminary data also indicates some issues with staining for some of the varieties. Due to the late harvest the grain quality results are not available at this stage. Please refer to the regional updates papers and the Wheat variety guide 2009 Western Australia for the grain quality results.

Preliminary results show that the largest range of falling numbers occurred at the Mt Barker with the May sowing times. The values ranged from below 80 seconds for Carnamah to above 350 seconds for EGA Eagle Rock. EGA Eagle Rock was also competitive with the highest yielding varieties at the mid May sowing at Mt Barker but had the lowest yields at the later sowings. Falling numbers at the later sowing date only ranged from 250 seconds for Carnamah to above 400 for EGA Eagle Rock. A similar range is associated with the early May sowing at Katanning where less late rain occurred. Although Newdegate received more late rain than Katanning, the later dates of sowing resulted in higher falling numbers generally.

KEY WORDS

wheat varieties, wheat agronomy, time of sowing, grain yields

ACKNOWLEDGMENTS

The assistance of Vicki Scanlan and the Research Support Units of the Department of Agriculture and Food, Western Australia at Mt Barker, Katanning and Newdegate and GRDC for funds are gratefully acknowledged.

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Table 1 **Grain yield (t/ha) response of wheat varieties to sowing time at the Mt Barker, Katanning and Newdegate Research Stations in 2008**

Grade	Variety	Mt Barker			Average	Katanning*				Newdegate			Average
		14 May	30 May	13 June		6 May	23 May	16 June	Average	16 May	4 June	26 June	
AH	Braewood	4.4	4.5	4.1	4.3								
	Carnamah	4.4	4.2	4.8	4.4	1.3	2.8	2.6	2.2	2.0	2.2	2.5	2.2
	EGA Bonnie Rock									2.7	2.2	2.4	2.4
	EGA Eagle Rock	4.5	3.5	2.9	3.6								
	EGA Gregory	3.7	3.8	3.3	3.6								
	Yitpi	4.1	4.0	3.8	4.0	2.8	3.3	2.9	3.0	2.8	2.5	2.6	2.6
APW	Annuello	3.9	4.1	3.6	3.9								
	Axe									2.5	2.4	2.2	2.3
	Carinya	3.8	4.1	4.0	4.0	2.4	3.2	2.9	2.8	2.4	2.2	2.6	2.4
	Catalina	4.1	3.8	3.6	3.8	1.8	3.0	2.5	2.4	2.5	2.6	2.6	2.6
	Correll	4.1	3.9	3.9	4.0	2.6	3.3	3.0	3.0		2.7	2.5	2.6
	Derrimut Wt	4.1	3.7	3.4	3.7					2.5	2.7	2.5	2.6
	EGA Bounty	4.3	4.6	4.3	4.4								
	EGA Wentworth	4.1	3.8	4.2	4.0								
	Endure (IGW2784)	4.0	4.1	4.3	4.1	3.2	3.0	2.6	2.9				
	Espada	3.9	3.8	3.7	3.8	2.0	3.0	2.8	2.6	2.8	2.6	2.4	2.6
	Fang (RAC1400)	4.2	4.0	4.0	4.0	3.0	3.2	3.1	3.1	2.7	2.6	2.5	2.6
	Gladius	3.8	3.7	3.9	3.8	1.8	2.8	2.7	2.5	2.7	2.8	2.6	2.7
	LRP Lincoln	4.3	4.0	3.7	4.0	1.7	3.2	3.0	2.6	2.5	2.5	2.5	2.5
	Mace (RAC1372)	4.5	3.7	4.0	4.1	1.9	2.9	2.7	2.5	**3.0**	2.5	2.4	2.6
	Magenta	**4.8**	**4.8**	4.4	**4.6**	2.6	3.1	2.9	2.9	2.9	**3.1**	2.7	**2.9**
	Wyalkatchem	4.2	3.9	4.3	4.2	1.2	3.2	2.5	2.3	2.4	2.4	2.1	2.3
	Young	3.9	4.0	4.4	4.1	1.2	2.4	2.6	2.1	2.7	2.9	**2.8**	2.8
	Zippy (IGW2838)					0.3	1.3	2.0	1.2	1.8	1.8	2.0	1.9
ASWN	Arrino									2.0	2.2	2.4	2.2
	Binnu					1.7	2.7	2.3	2.2	2.3	2.3	2.5	2.4
	Calingiri	4.3	4.4	4.3	4.3	3.4	3.0	2.7	3.0	2.5	2.7	2.5	2.6
	Fortune (IGW2856)					3.1	3.0	**3.1**	3.1	2.7	2.5	2.7	2.6
	Yandanooka					1.5	2.3	3.0	2.3	2.3	2.5	2.2	2.3
ASFT	Bullaring					3.1	**3.5**	2.6	3.1				
	Datatine					2.8	3.0	2.5	2.8				
	EGA 2248					2.2	2.6	2.7	2.5				
	EGA Jitarning	4.2	4.3	**4.7**	4.4	**3.5**	3.5	2.8	**3.2**	2.9	2.6	2.6	2.7
	Average	*4.1*	*4.0*	*4.0*	*4.1*	*2.2*	*2.9*	*2.7*	*2.6*	*2.5*	*2.5*	*2.5*	*2.5*
		Fpr	l.s.d.			Fpr	l.s.d.			Fpr	l.s.d.		
	TOS	0.798	0.7			0.149	0.8			0.899	0.4		
	Variety	< .001	0.4			< .001	0.3			< .001	0.2		
	TOS*Variety	0.050	0.8 (0.6)			< .001	0.8 (0.6)			< .001	0.5 (0.3)		
	CV (%)	9.5				13.6				7.7			

* Katanning was severely affected by frost.

Flowering dates of wheat varieties in 2008 at three locations in Western Australia

Darshan Sharma, Brenda Shackley and **Christine Zaicou-Kunesch**, Department of Agriculture and Food, Northam, Katanning and Geraldton, Western Australia

KEY MESSAGES

The phenology experiments examined a range of maturities available in Western Australia, including the extremely late EGA Wedgetail and the early Zippy.

Some cultivars behave differently if sown too late or too early and this effect is also location specific.

Cultivars tended to flower later in 2008 compared to 2007.

AIMS

The aim of this article is to provide growers with a decision support information that could be used to manage frost and screenings risks to wheat crops in Western Australia.

METHOD

About 50 wheat lines were grown at four different sowing dates at three locations selected on the basis of day length and minimum and maximum temperatures over three years. The locations were: Geraldton, Northam and Katanning. Sowing was undertaken in unreplicated, one metre long rows with three repeated checks.

Observations on the number of heads showing anthesis were recorded at 2–3 days intervals and date of 50% anthesis was calculated. Anthesis or flowering date is the date when 50% of the heads are showing yellow anthers. Heading was also recorded by a similar method but not presented. Parameters for Flowering Calculator V0.91 were also calculated on the basis of pooled data from 2006, 2007 and 2008 but predictions are not presented here. Instead, in line with 2006 and 2007, the actual flowering dates of varieties tested in 2008 are shown in **Table 2**.

RESULTS

Mid-anthesis dates of 30 wheat cultivars are given in Table 1. The colour coded maturity groups in this table are relative to other varieties when sown at the same time. The extremely late and early maturity ‘checks’ were cultivars EGA Wedgetail and Zippy, respectively.

Compared to Wyalkatchem, the new release Mace flowered a few days later at Geraldton and Northam (unless sown mid-June) but was slightly quicker at Katanning. In the south, Magenta, Fang and Yitpi appear to have similar flowering times, all being slightly later than Wyalkatchem. The new noodle release Fortune took slightly longer time to flower than Calingiri when sown early, but the trend at later sowing in Katanning was the opposite. Endure is an option for early break, as it was consistently a cultivar of long duration across all sites.

A frost event at the Katanning site on 22 September caused a large amount of head damage and did led to difficulties in recording the anthesis times. Some varieties appearing to ‘flower’ later although this was also confounded with the overall lower temperature in 2008 (see below).

Effect of season

Compared to 2007 (refer to Agribusiness Crop Updates Cereals book 2007), most cultivars flowered later in 2008 and the difference was greatest at the late-April, mid-May and early-June sowing dates at Katanning, Northam and Geraldton, respectively. These differences most probably reflect the influence of temperature profiles at these locations over two seasons but a clear attribution is difficult without proper analysis. Nonetheless, a simple conclusion could be drawn that a difference in 1–2 degrees in winter temperature (June-July) could correspond to a flowering date difference of about up to two weeks.

Please note the extra maturity class of 'very long duration' include in Table 1 compared to the 2007 table. Comparisons of the areas shaded between the two years will not be relevant due to the different spread of the maturity classes. The data is now more in line with the maturity classifications used elsewhere.

Sown too early

When sown too early (24 April), cultivars Carinya, Correll and Gladius, which otherwise belonged to medium maturity groups, tended to flower early like short season cultivars.

Sown too late

When sown too late (20 June) at Geraldton, Magenta tended to behave more like a long duration rather than a medium-long season cultivar. In contrast, cultivars Binnu, EGA Jitarning and perhaps Gladius and Fang when sown late at Katanning, tended to flower relatively sooner or quicker.

CONCLUSION

Flowering date depends upon sowing date, location, season and varietal response. Some cultivars when sown too early will tend to flower earlier. When sown late, most of the cultivars will tend to flower relatively earlier or quicker.

KEY WORDS

flowering date, anthesis, heading date, wheat, agronomy, new varieties, phenology

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Table 2 **Flowering date* for 30 wheat varieties at different sowing dates at three locations in Western Australia in 2008**

Grade	Variety	Geraldton				Northam				Katanning			
		24 Apr	16 May	3 Jun	20 Jun		16 May	3 Jun	20 Jun	24 Apr	16 May	3 Jun	20 Jun
AH	Carnamah						15 Sep	26 Sep	2 Oct	12 Sep	28 Sep	3 Oct	17 Oct
	Yitpi						19 Sep	30 Sep	6 Oct	24 Sep	30 Sep	11 Oct	20 Oct
APW	Axe	27 Jun	22 Jul	19 Aug	2 Sep		10 Sep	22 Sep	28 Sep	5 Sep	21 Sep	2 Oct	9 Oct
	Bolac	12 Jul	15 Aug	4 Sep	17 Sep		26 Sep	4 Oct	13 Oct	24 Sep	8 Oct	17 Oct	23 Oct
	Carinya	3 Jul	8 Aug	2 Sep	14 Sep		17 Sep	29 Sep	4 Oct	14 Sep	3 Oct	12 Oct	21 Oct
	Catalina	1 Jul	27 Jul	23 Aug	6 Sep		16 Sep	24 Sep	1 Oct	9 Sep	29 Sep	9 Oct	19 Oct
	Correll	7 Jul	6 Aug	1 Sep	14 Sep		17 Sep	24 Sep	3 Oct	14 Sep	29 Sep	11 Oct	18 Oct
	Derrimut	3 Jul	1 Aug	28 Aug	10 Sep		18 Sep	26 Sep	3 Oct	10 Sep	30 Sep	9 Oct	17 Oct
	EGA Bounty	13 Jul	9 Aug	30 Aug	14 Sep		21 Sep	25 Sep	3 Oct	19 Sep	5 Oct	15 Oct	22 Oct
	EGA Wedgetail		***23 Sep***	***30 Sep***	***15 Oct***		***7 Oct***	***11 Oct***	***16 Oct***	***9 Oct***	***13 Oct***	***19 Oct***	***26 Oct***
	Endure (IGW2784)	17 Aug	2 Sep	12 Sep	25 Sep		29 Sep	3 Oct	8 Oct	8 Oct	12 Oct		29 Oct
	Espada	12 Jul	7 Aug	30 Aug	11 Sep		17 Sep	24 Sep	28 Sep	17 Sep	3 Oct	10 Oct	19 Oct
	Fang (RAC1400)	3 Aug	21 Aug	6 Sep	16 Sep		23 Sep	30 Sep	1 Oct		2 Oct	12 Oct	15 Oct
	Gladius	13 Jul	6 Aug	29 Aug	11 Sep		13 Sep	24 Sep	30 Sep	13 Sep	30 Sep	7 Oct	12 Oct
	Lincoln	8 Jul	28 Jul	26 Aug	9 Sep		12 Sep	24 Sep	27 Sep	6 Sep	27 Sep	6 Oct	20 Oct
	Mace (RAC1372)	9 Jul	8 Aug	29 Aug	11 Sep		16 Sep	23 Sep	30 Sep	8 Sep	25 Sep	2 Oct	12 Oct
	Magenta	15 Jul	11 Aug	4 Sep	18 Sep		23 Sep	30 Sep	6 Oct	17 Sep	2 Oct	9 Oct	18 Oct
	Spear									24 Sep	1 Oct	10 Oct	23 Oct
	Westonia	2 Jul	22 Jul	21 Aug	8 Sep		11 Sep	21 Sep	28 Sep	3 Sep	24 Sep	3 Oct	
	Wyalkatchem	4 Jul	30 Jul	25 Aug	12 Sep		14 Sep	21 Sep	2 Oct	13 Sep	30 Sep	9 Oct	17 Oct
	Zippy (IGW2838)	26 Jun	18 Jul	16 Aug	2 Sep		5 Sep	15 Sep	26 Sep	9 Sep	21 Sep	2 Oct	9 Oct
ASWN	Arrino	1 Jul	29 Jul	30 Aug	12 Sep		16 Sep	23 Sep	8 Oct	8 Sep	29 Sep	2 Oct	12 Oct
	Binnu	18 Jul	30 Jul	26 Aug	8 Sep		17 Sep	5 Oct	5 Oct	17 Sep	1 Oct	9 Oct	15 Oct
	Calingiri	18 Jul	14 Aug	4 Sep	16 Sep		19 Sep	27 Sep	3 Oct	21 Sep	10 Oct	16 Oct	20 Oct
	Fortune (IGW2856)	24 Jul	17 Aug	3 Sep	16 Sep		26 Sep	29 Sep	5 Oct	23 Sep	3 Oct	12 Oct	15 Oct
	Yandanooka	16 Jul	7 Aug	1 Sep	15 Sep		16 Sep	22 Sep	7 Oct	16 Sep	26 Sep	10 Oct	19 Oct
ASFT	Bullaring						25 Sep	29 Sep	10 Oct	24 Sep	10 Oct		
	EGA2248						14 Sep	24 Sep	27 Sep	15 Sep	25 Sep	6 Oct	12 Oct
	EGA Jitarning						24 Sep	28 Sep	9 Oct	26 Sep	5 Oct	12 Oct	19 Oct
ASW	Bumper (IGW2836)	18 Jul	12 Aug	1 Sep	13 Sep		14 Sep	29 Sep	1 Oct	10 Sep	26 Sep	5 Oct	12 Oct

Very Long duration | Long duration | Medium duration | Short duration

Empty cells = Data was not available this year.

Maturity classes in this table could be different from previous years because this year the data has been classified into four instead of three categories in order to make it more user-friendly.

Agronomic responses of new wheat varieties in the northern agricultural region in 2008

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KEY MESSAGES

In a season with good summer rain and finishing rains in September the delay in seeding had a greater effect on yield decline on the sandplain at Mingenew than the loamier soils at Marchagee and Mullewa.

Axe and Zippy (early maturing) did not yield significantly better than most other varieties sown in June but tended to have better screenings levels.

The season favoured the performance of longer maturing varieties. Magenta was a high performing variety in the majority of trials in the northern agricultural region however this variety is very susceptible/susceptible to blackpoint.

AIMS

To assess the performance of recently released varieties, particularly Axe, Bumper, Espada, Fortune, Gladius, Mace, Magenta and Zippy, in the northern agricultural region (NAR).

METHOD

Field based agronomy trials were conducted in 2008 on yellow sandplain at Mingenew (Agzone 1), loamy sand at Marchagee (Agzone 2) and sandy loam at Mullewa (Agzone 4). Twenty four varieties from various wheat breeding organisations were sown at three sowing times in a randomised split block design.

Sowing times were 2 May, 10 June and 24 June at Mullewa, 1 May, 16 May and 12 June at Marchagee and 1 May, 20 May and 18 June at Mingenew. April to October rainfall was 223.8 mm at Mullewa (95 mm was recorded for January to March), 324 mm at Marchagee and 278 mm at Mingenew.

Information available through the National variety testing program (NVT) and phenology trials conducted in 2008 has also been utilised for discussion in this paper.

Note: Full grain quality data not available at time of printing.

RESULTS

Time of sowing response—across all varieties

There was a decline in yield of 20 kg/ha/day at Mingenew (average across all varieties) when seeding was delayed from early May to mid May compared to an increase in yield by 30 kg/ha/day (average across all varieties) at Marchagee during the same period (Figure 1). The second sowing opportunity was six weeks after the first at Mullewa. The decline in yield during this period was 15 kg/ha/day (2 May–10 June). Growing season rainfall was greater at Marchagee than Mingenew. September and October rain was 73 mm at Marchagee and 44 mm at Mingenew.

Figure 1 Average grain yields at Mullewa (◇), Mingenew (□) and Marchagee (△) when sown at various times between early May and late June in 2008.

Sowing wheat options—APW

The recently released variety Mace (AGT1372) flowered on average 3 days later than Wyalkatchem (average over 4 sowing times) in the northern districts. It has a preliminary classification of APW (final classification in April 2009). Mace has a good resistance to stem (mod resistant provisional), stripe (resistant/moderately resistant) and leaf rust (resistant provisional). It has a provisional black point resistance rating of moderately resistant which was confirmed by the lower incidence of blackpoint in Mace compared to other varieties at the Mingenew site.

Mace performed similarly to Wyalkatchem in the 2008 NVT trial program at all locations in the NAR except Marchagee. However, in time of sowing trials at Marchagee and Mingenew, Mace was one of the highest yielding varieties. In contrast Mace was lower yielding than Wyalkatchem when sown on 2 May on the sandy loam at Mullewa, but yielded similarly at the other sowing times.

Magenta sown in the first week of May was the top yielding APW variety at each of the time of sowing trials in 2008 and yielded significantly better than Wyalkatchem. Magenta performed similarly to Wyalkatchem and was amongst the highest yielding varieties in the 2008 NAR NVT trials sown in the second week of May at Carnamah on loamy clay, Pithara on sandy loam and Marchagee on loam. Magenta outyielded Wyalkatchem in the NVT trial at Maya. The NVT long term yield (2000–07) of Magenta is similar to Wyalkatchem.

Magenta has a long coleoptile and good leaf disease profile however it is very susceptible/susceptible to pre harvest sprouting. In 2008 at Geraldton, Magenta flowered about ten days later than Wyalkatchem and is considered mid-long maturity. Screenings may be an issue if Magenta is sown in late May or June.

Espada and Gladius recorded yields below the highest yielding varieties in both the NAR NVT and time of sowing trials in 2008. However, long term NVT yields (2000–07) indicate that Gladius yields are only slightly lower than Wyalkatchem (97%) and Espada yields are similarly to Wyalkatchem. Espada is moderately susceptible/susceptible to blackpoint and Gladius is moderately resistant.

Early maturing varieties Axe and Zippy sown in June 2008 yielded similarly or lower than other varieties, however they had slightly better screening levels (data not published). In 2007 the rainfall recorded was much lower than 2008, however around 20–25 mm of rain fell in September. Axe performed similarly to the majority of other APW wheat varieties sown in June or July in this year. The performance of these varieties in a dry finish is yet to be determined. Axe flowered 8 days earlier and than Wyalkatchem and Zippy flowered 10 days earlier than Wyalkatchem in 2008 at Geraldton (average across 4 sowing times).

The ASW variety Bumper yielded similarly or lower than Wyalkatchem in all NAR NVT trials in 2008. The NVT long term yields (2000–07) of Bumper are similar to Wyalkatchem. Bumper was only included in the TOS trial at Mullewa and its performance was similar to Wyalkatchem at each seeding time between early May and late May. Bumper is unlikely to attract better returns than leading APW varieties based on yield results (assuming APW offers a premium over ASW).

Sowing wheat options—ASWN

Binnu, Yandanooka and Fortune all performed similarly and their respective yields were not significantly different to those of Calingiri at most sowing times across all sites. The yields of Calingiri were significantly higher than Binnu with 2 May sowing at Mullewa and Marchagee, where Calingiri also out yielded Yandanooka. Yandanooka is taller than the other varieties and stubble management in higher yielding crops may be a consideration where subsequent cropping is planned for the paddock. Binnu had higher screenings than the other noodle varieties at Mingenew, however levels did not exceed 5% (data not published). Binnu, Fortune and Yandanooka all have better noodle quality than Calingiri and provide some improvements in disease resistance (refer to Wheat variety guide 2009 Western Australia). Fortune flowered 6 and 3 days later than Calingiri in the 2008 phenology trials when sown in early April and mid May.

Sowing wheat options—AH

Carnamah yielded well across all sowing times on the sandy loam at Mullewa in 2008 but on the sandplain soils at Mingenew the relative performance of this variety declined considerably with delayed seeding. In general, across all three time of sowing trials, Carnamah outperformed EGA Bonnie Rock in 2008 however screenings were similar and within industry standards (data not published). The NVT long term yields (2000–07) of Carnamah and EGA Bonnie Rock are similar. EGA Bonnie Rock is very susceptible to stripe rust. Carnamah is very susceptible to sprouting. Tammarin Rock out performed EGA Bonnie Rock, however its resistance to black point is poor compared to EGA Bonnie Rock.

CONCLUSION

Good summer rain and finishing rains in September and October favoured the relative performance of the longer maturing varieties.

Early May seeding resulted in significantly higher yields than later sowing, however the delay in seeding had a greater effect on yield decline at Marchagee and Mingenew than at Mullewa.

The performance of many of the new wheat varieties was comparable, or better in some situations, than that of commercial favourites. The results for Mace, Magenta and the three new noodle varieties Binnu, Fortune and Yandanooka in particular justify their consideration as replacements for older varieties.

KEY WORDS

wheat varieties, agronomy, crop management, time of sowing

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Table 1 **Effect of sowing time on yield (t/ha) of wheat varieties at Mingenew, Mullewa and Marchagee in 2008**

		Mingenew			Ave	Mullewa			Ave	Marchagee			Ave
		1 May	20 May	18 June		2 May	10 June	24 June		1 May	16 May	12 June	
AH	Carnamah ф	4.19	3.42	1.03	2.88	4.81	3.47	2.46	3.58	4.94	5.15	3.92	4.67
	EGABonnieRock ф	3.56	3.76	1.15	2.82	3.36	3.09	2.37	2.94	4.36	4.50	3.87	4.24
	TammarinRock ф	3.75	4.27	1.30	3.11	3.60	3.60	2.61	3.27	3.85	4.70	3.65	4.07
	Yitpi ф	4.07	3.19	1.37	2.88					4.61	4.46	3.78	4.28
APW	Axe ф	2.54	2.48	1.03	2.02	2.98	3.03	2.01	2.67	2.27	3.64	3.35	3.08
	Carinya ф	3.52	2.28	0.78	2.19	4.00	3.01	1.95	2.99	4.12	4.34	3.17	3.88
	Catalina ф	2.98	3.41	1.03	2.48	3.65	3.25	2.15	3.02	3.40	4.30	3.91	3.87
	Correll ф	4.24	3.35	1.24	2.94	3.99	3.37	2.29	3.22	4.22	4.86	3.46	4.18
	Derrimut Wt ф	2.48	2.65	0.73	1.95	3.59	3.28	2.21	3.03	2.93	4.14	3.51	3.53
	EGAWentworth ф	3.04	2.73	0.74	2.17	3.48	2.89	1.86	2.74	3.99	4.11	3.39	3.83
	Espada ф	3.87	3.68	1.17	2.91	3.77	3.23	2.30	3.10	4.11	4.59	3.64	4.11
	Gladius ф	3.75	3.46	1.36	2.85	4.22	3.18	2.16	3.19	4.11	4.63	3.71	4.15
	LRPLincoln ф	4.60	2.65	1.04	2.76	3.93	3.37	2.25	3.18	4.05	4.62	3.36	4.01
	Mace ф	4.12	3.79	1.44	3.12	3.66	3.55	2.67	3.29	5.08	5.40	3.66	4.71
	Magenta ф	4.71	4.17	1.16	3.35	5.07	3.76	2.30	3.71	5.72	5.36	3.98	5.02
	Wyalkatchem ф	4.54	3.85	1.38	3.26	4.45	3.62	2.37	3.48	4.76	5.27	3.65	4.56
	Young ф	3.05	3.46	1.12	2.54	3.12	3.34	2.17	2.88	3.63	4.68	3.73	4.02
	Zippy ф	2.62	2.82	1.14	2.19	2.30	3.17	2.12	2.53	2.84	4.40	3.55	3.60
ASW	Bumper ф					4.71	3.51	2.31	3.51				
ASWN	Arrino ф	3.74	3.35	1.23	2.77	4.27	3.57	2.16	3.33	4.22	4.83	3.61	4.22
	Binnu ф	4.24	3.88	1.00	3.04	4.46	3.30	2.21	3.32	4.70	4.94	3.61	4.42
	Calingiri ф	4.46	3.87	1.22	3.18	5.34	3.58	2.51	3.81	5.41	4.89	3.73	4.68
	Fortune ф	4.12	3.54	0.98	2.88	4.88	3.58	2.38	3.61	5.06	5.13	3.69	4.63
	Yandanooka ф	4.20	3.66	1.03	2.96	4.31	3.55	2.52	3.46	4.99	4.97	4.31	4.76
	Average within eachTOS	3.75	3.38	1.12	2.75	3.98	3.36	2.28	1.20	4.24	4.69	3.66	4.20
	TOS (l.s.d.)	0.32		Var (l.s.d.)	0.25	0.73		Var (l.s.d.)	0.25	0.15		Var (l.s.d.)	0.24
	Var (l.s.d.) between TOS	0.44		%CV	10	0.75		%CV	8.3	0.42		%CV	6
	Var (l.s.d.) within TOS	0.49				0.42				0.42			