VALUE ADDED WHEAT CRC
FINAL REPORT

Project 4.3.8

Development of Adapted Wheats and Varieties

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Executive Summary

The sustainability and international competitiveness of the Australian wheat industry is dependent on the development of improved varieties that will increase economic returns to growers, processors and manufacturers of wheat end products. The development of Australian wheat varieties that have greater yield potential, superior processing properties and improved end product quality is limited by the absence of novel sources of extremes of characters that influence these attributes. Furthermore, where they are known the agronomic characteristics of such material is so undesirable that private breeders do not readily employ them in germplasm development programs.

This project aimed to develop elite germplasm that possesses extremes of important agronomic, processing and end product quality characters and also to perform QTL mapping in relevant populations.

This report outlines the activities that were conducted in project 4.3.8 of the VAWCRC Ltd.

Introduction

The level of genetic diversity is low in existing Australian bread and durum wheat varieties and breeders germplasm. As a result there is little variation in important agronomic and quality characters that may affect production, processing and end product quality in advanced breeding germplasm and the potential for advancement in these characters is severely limited.

There is a real need to develop improved bread and durum wheat germplasm to improve the economic return of growers, processors and end product manufacturers to ensure continuing international competitiveness and sustainability of the wheat industry.

This work was conducted to develop germplasm that possesses novel variation of important agronomic and quality characters. This material would either be suitable for commercial production or would represent improved elite parent material that would contribute to the national breeding effort.

Target characters for incorporation into adapted breadwheat germplasm include null polyphenol oxidase (PPO) activity, large grain size (60^{+}g thousand kernel weight), sprouting tolerance, extremes of water soluble pentosans which contribute to water absorption, and extremes of starch granule size distribution. Sources of extremes of these characters were identified in QWCRC project 1.1.1 and VAWCRC project 4.1.1.

Target characters for durum wheat include low starch swelling power, extremes of starch b granule content and reduced blackpoint incidence.

Researchers at The University of Sydney Plant Breeding Institute (Matthew Turner, Akram Khan and Nizam Ahmed) and The Department of Primary Industries; The Tamworth Agricultural Institute (Mike Sissons) and PhD students participated in the project.

Materials and Methods

Populations were generated using the wheat x maize doubled haploid approach or single seed descent. Details of all populations are provided in Appendices 1 and 2.

Populations were phenotyped according to the following protocols

Field evaluation of rust reactions

Land preparation and seed sowing

A recommended dose of inorganic fertilizer was applied during land preparation. The pre-emergent herbicide Glean® was applied at the rate of 1g/20L of water. The field was irrigated with sprinklers as and when necessary. Seeds were sown 8-10cm apart in 2m rows. The parents were sown as a control along with the population.

Field inoculations

The experiments were conducted at Landsdowne Farm (PBIC) with 2 replications. The experimental area was inoculated with the following pathotypes (Table 1) by the Rust group of PBIC.

Table 1 Pathotypes used in field studies

Rust	Pathotype
Puccinia triticina	104-1,2,3,(6),(7),9,11 [=521]
	104-1,2,3,(6),(7),11,13 [=547]
	10-1,3,7,9,10,12 [=592]
	76-3,5,9,10 +Lr37 [=594]
Puccinia striiformis	134 E16A+ [=572]
	104E137A- [=544]

Rust response assessment

The scale of rust assessment (1 to 9 scale) at adult plant stages are summarised for stripe rust and leaf rust in Table 2 and Table 3, respectively

Determination of grain PPO activity

PPO activities were measured using tyrosine (Bernier and Howes 1994 and McCaig *et al.* 1999) as substrate. The PPO assays that used tyrosine as substrate were conducted at The Plant Breeding Institute, Cobbitty, The University of Sydney.

Tyrosine substrate

The grain PPO activities were assayed using tyrosine as substrate as described in Bernier and Howes (1994) and McCaig *et al.* (1999).

Table 2 The scale of assessment of adult plant stripe responses.

Score	Description
1	Highly resistant: no visible symptoms
2	Highly resistant: occasional symptoms of infection including necrotic flecks and small stripes without sporulations
3	Resistant: symptoms evident and may include stripes with necrosis and chlorosis, limited sporulations, and effected leaf area up to 15%
4	Moderately resistant: sporulating areas arranged in stripes, some chlorosis and necrosis, and effected leaf area up to 30%
5	Intermediate: sporulating areas arranged in stripes with some chlorosis, and affected leaf area up to 50%
6	Moderately susceptible: sporulating stripes and effected leaf area up to 70%
7	Moderately susceptible to susceptible: sporulating stripes merging into broader leaf areas supporting symptoms; chlorosis necrosis evident; leaf area affected up 90%.
8	Susceptible: sporulation across the whole leaf surface with no stripes but with evidence of chlorotic areas.
9	Highly susceptible: abundant sporulation across the whole leaf area with no evidence of stripes.

(After, Wellings and Bariana, 2004)

Table 3 The scale of assessment of adult plant leaf rust responses in field.

Scale	Response	Leaf rust
1	Very resistant	No disease
2	Resistant	<5% necrotic dots with/without occasional medium
3	Resistant to Moderately resistant	10-15% severity, pustule size and response may vary between genotypes
4	Moderately resistant	20-30% severity, pustule size and response may vary between genotype
5	Moderately resistant to Moderately susceptible	35-45% severity, pustule size and response may vary between genotypes with light to moderate sporulation
6	Moderately susceptible	50-60% severity, pustule size may vary
7	Moderately Susceptible to Susceptible	65-75% severity with moderate sporulation
8	Susceptible	80-90% severity with heavy sporulation
9	Very susceptible	95-100% severity, heavy sporulation leading to defoliation

(Adopted from Bariana *et al.* 2005)

Chemical and equipment

Ten whole seeds for each line were incubated in 0.01 M disodium tyrosine solution with 0.2% Tween 20 at 37^0C for 3.5 hours, and, after leaving the seeds, the absorbance of the solution was measured at 450nm using Bench Mark Plus – Microplate Spectrophotometer (BIORAD laboratories).

Substrate preparation

Tyrosine substrate was prepared with Tween 20, Tyrosine (L- Tyrosine disodium salt, Batch no. 074k1367, Sigma) and Tris base. Tween20 (4ml) was made up to 20ml with water. Tyrosine (0.45g) and Tris base (2.42g) were dissolved in 160ml of distilled water by stirring. The pH was adjusted to 9 with approximately 1M HCl. Then the solution was mixed with 20 ml of Tween 20 solution and made up to a final volume of 200ml with distilled water.

Assay procedure

A single sound grain was placed in each well, except the wells in one row that served as a reagent blank. Ten seeds per line were used for this assay. Tyrosine reagent (200µl) was added to each well with a multichannel pipette. The microtitre plates were covered with a lid and incubated at 37^0C for 4 hours. A portion of (100µl) the solution was removed from each well with a multi-channel pipette and placed in a second microtitre plate, ensuring that no bubbles were in the wells. The optical density (O.D.) was determined in a microplate reader at 450nm.

Visual Confirmation of Null PPO lines

The grains were also compared by visual observation especially to validate lines that were idenitified to possess null PPO activity. After a 4 hour incubation at 37^0C plates were kept at 22^0C for 96 hours before visual observation.

Determination of starch B granule content

A hybrid between cultivar Yallaroi and a low %B-granule *T dicoccoides* accession, 3810 (~18% B-granules) was self pollinated and a population of 53 F2 derived F3 lines were generated.

A hybrid between cultivar Yallaroi and a high %B-granule *T dicoccoides* accession, 3581 (~40% B-granules) was self pollinated and a population of 164 F2 derived F3 lines were generated.

Populations were grown at the Tamworth Agricultural Institute in the field under a conventional tillage production system.

Heads were harvested intact at maturity and threshed. The starch was extracted from grain and cleaned for particle size analysis (Stoddard 1999). The %B-granule content in the isolated starch (volume percentage) was measured using a laser diffraction particle size analyser (Malvern Mastersizer 2600C). Particle sizes were calculated on Mie theory based on spheres of equivalent volume and were presented as diameters.

Grain size

Doubled haploid populations from a hybrid between the large grain selection and cultivar Lang were generated in project 4.1.1. These were grown at EMAI and evaluated for grain size and shape. The largest of these that possessed a highly desirable round shape was hybridised with cultivar Lang and a small DH population was developed. (Appendix 1). This population needs to be evaluated.

Evaluation of blackpoint incidence

Three populations of plants prepared by Dr Hare between two mr and elite germplasm have been produced (F3) in 2005. Crosses were between lines 980086 (32%BPt) X 981151 (7%BPt); 981190 (14%) X 200903 (35%BPt); 980103 (12% BPt) X 201177 (35% BPt). These were evaluated for BPt susceptibility to search for plants having greater resistance than either parent in 2006 field trials (n=490 plots).
Blackpoint was evaluated as described in The VAWCRC project 4.1.1 final report.
All analyses were determined by visual observation, to ensure accuracy.
Two populations were also developed by Dr Turner (980103 X Bellaroi) and 980103 X MS4105).

Yield Trials, Milling and Quality Tests

Yield trials were conducted in a RCBD consisting of two replicate 6m x 2m plots of each line at PBIN. All milling and quality tests were performed or supervised by John Dines according to procedures used at Allied Mills.

Results

Hexaploid Wheat Populations

Null PPO

Genetic mapping of PPO loci in Qalbis//Lang/Null PPO synthetic DH population
Three major loci and three minor loci were identified in the QTL mapping study over two seasons. Each of these were in corresponding locations on the group two chromosomes (Table 4).

Table 4 QTLs controlling PPO activity in the QALBis x VAW08-A17 doubled haploid population.

Site-Year	Chromosome Locations	QTLs	Closest marker	LRS[1] value	`PVE[2](%)	Parents (+ve PPO)
Cobbitty-2005	1B	*QPPO.qp-1B*	wPt-1403	5.6	6	VAW08-A17
	2A	*QPPO.qp-2A*	PPO18	14.9**	16	QALBis
	2B	*QPPO.qp-2B*	wPt-0094	16.8**	17	QALBis
	2D	*QPPO.qp-2D*	wPt-2544	24.7**	28	QALBis
	7A	*QPPO.qp-7A*	wPt-4835	5.9	6	QALBis
Narrabri-2006	1B	*QPPO.qp-1B.*	wPt-1403	4.4	5	VAW08-A17
	2A	*QPPO.qp-2A*	wPt-7024	23.9**	24	QALBis
	2B	*QPPO.qp-2B*	wPt-0094	16.1**	17	QALBis
	2D	*QPPO.qp-2D*	wPt-2544	27.5**	28	QALBis
	3B	*QPPO.qp-3B*	wPt-5892	13.2**	14	QALBis
Pooled	1B	*QPPO.qp-1B*	wPt-1403	6.5*	7	VAW08-A17
	2A	*QPPO.qp-2A*	wPt-7024	20.1**	20	QALBis
	2B	*QPPO.qp-2.B*	wPt-0094	21.0**	21	QALBis
	2D	*QPPO.qp-2D*	wPt-2544	31.6**	33	QALBis
	3B	*QPPO.qp-3B*	wPt-5892	9.2*	10	QALBis
	7A	*QPPO.qp-7A*	wPt-4835	5.2	6	QALBis

[1]Likelihood statistic ratio. [2]Phenotypic variation explained. Asterisk (*) and (**) indicate significant level at P>0.01 and P>0.001, respectively. Non asterisk LRS values indicate the suggestive level (P>0.05).

*Selections from Lang*2/null PPO synthetic and QalBis//Lang/Null PPO synthetic DH populations*

21 lines from the Lang*2/null PPO synthetic population (originally 140lines) and 8 lines from the QalBis//Lang/Null PPO synthetic population (originally 203 lines) were trialled in 2007.

The yield of a number of these lines was greater than the highest checks. The material exhibited moderate resistance to stripe rust in 2007 at PBIN (Table 5). A range of PPO activities was observed in this material from null PPO to high PPO (Table 5).

Table 5 Stripe rust reaction, mean plot yield and PPO activity of selected lines from the null PPO breeding effort

ID	Yr Field Reaction	Mean Plot Yield (g)	PPO activity	
			2005	2006
LP262	2	2264	0.32	0.16
LP287	2	2306	0.13	0.14
LP273	2	2348	0.12	0.14
LP250	3	2356	0.05	0.02
LP249	2	2361	0.41	0.28
QP083	2	2382	0.17	0.32
LP275	2	2401	0.13	0.12
LP215	2	2456	0.45	0.25
QP090	2	2500	0.29	0.28
LP265	3	2550	0.14	0.08
LP306	2	2567	0.16	0.24
LP234	4	2703	0.03	0.01
Sunco	2/3	2011	0.27	0.24
H45	8	2374	0.40	0.56

Quality testing and further yield testing is required to evaluate this material.

Large grain size

Selections from Lang/large grained synthetic wheat DH populations were crossed to Lang to generate elite material that possess the character. This material need to be evaluated in the field immediately.

Water Extractable Pentosans

Crosses aimed at targeting high and low water extractable pentosans were performed. Crosses aiming to introgress into low soluble pentosans into elite soft wheat backgrounds were Angas x QalBis and QalBis x Syn7.

A doubled haploid population of the former is generated, A single seed descent population (F3) of the latter is also available (Appendix 1). Both of these populations have not been progressed to an adequate stage for phenotyping.

Variety Goldmark that possesses high water soluble pentosans, high water absorption and high milling yield was crossed with DM5637*b8 and a doubled haploid population was generated. It was grown in 2007 at PBIN. Milling yield, water absorption and water soluble pentosan data will be measured from the trial. This research is being continued as part of a PhD project. QTL mapping will be performed.

Extremes of Starch Granule Size Distribution

A population was generated from a QAL2000 x outlier 67 (Low b granule hexaploid winter club wheat) hybrid. The material was selected in the F2-F4 for habit, maturity, head type and rust resistance. Starch granule size distribution was measured in F3 seed bulks. Rust testing was conducted by the ACRCP at PBIC and at EMAI by Matthew Turner and Akram Khan.
Selections were made at EMAI from 2003-2006.
The lines were incorporated into the soft wheat breeding program and were trialled in the s2 and s3 trials from 2006. Quality, yield and rust resistance data is available in the final report of the soft wheat breeding program.

Sprouting Tolerance

Material from a DM5637*B8 x H45 population that was part of a sprouting tolerance project 4.2.6 was transferred to project 4.3.8 in 2006. Since that time the sprouting tolerant lines and high yielding material were evaluated in yield trials (see project 4.1.3) results. Rust test results are shown in Table 6. Some quality testing was conducted. Milling results are presented in Table 7 and Yellow alkaline noodle results are presented in Table 8. QTL mapping was performed in this population for PPO activity, yellow alkaline noodle brightness and colour stability, and flour colour. It was identified that the major locus regulating PPO activity on chromosome 2A also controlled the change in brightness and yellowness of yellow alkaline noodles.
Four lines were included in the S3 trials of the soft wheat program in 2007 and quality tests are underway.

Table 6 Scores for resistance to the three wheat rusts.

YEAR	**2006**			**2007**	
RUST	**YR**	**LR**	**SR**	**YR**	**LR**
ID					
A101	4/5	2	3	2/3	2
A103	3/4	5	5	2/3	3
B17	3	¾	2	2/3	5
B30	5	4	5	4	¾
C32	3	2/3	2	2	¾
C35	3	2/3	2	2	2/3
C54	2/3	¾	2	3	3
H45	5/6	2/3	5	5/6	*
DM	2/3	2/3	2	2	2

* Yield trial conducted at PBIN

Table 7 Milling results for the DM x H45 selections.

	NIR Protein		Flour Extraction (%) Quadromat Jr		Flour Colour Components L*		Flour Colour Components a*		Flour Colour Components b*		Grain PPO activity Tyrosine A450	
ID	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**
A101	13.8	14.1	60.33	58.27	93.05	92.77	0.59	0.32	8.11	8.66	0.26	0.29
A103	13.35	13.55	61.28	60.18	93.065	92.40	0.33	0.23	9.17	9.76	0.33	0.24
B17	14.05	14.95	60.62	59.14	93.625	92.26	0.07	-0.02	9.155	10.26	0.20	0.17
B30	13.2	13.4	60.35	57.38	93.34	92.75	0.63	0.46	7.37	7.91	0.17	0.16
C32	13.35	14	59.16	61.52	93.375	92.26	0.385	0.26	8.465	9.76	0.29	0.29
C35	14.3	15.1	61.00	62.61	93.15	91.92	0.34	0.15	9.61	11.06	0.17	0.15
C54	14.4	14.9	61.62	61.46	93.09	92.07	0.395	0.12	9.16	9.80	0.18	0.17
DM5637*B8	14.75	14.8	60.95	60.75	93.33	91.95	0.45	0.28	8.595	9.59	0.14	0.16
H45	12.75	13.5	58.15	61.10	93.62	92.44	0.38	0.23	7.91	9.22	0.37	0.35

Table 8 Yellow Alkaline noodle results

	Yellow Alkaline Colour (24 hours) and Colour Stability (0-24hours)											
	L24		**L0-24**		**b24**		**b0-b24**		**a24**		**a0-24**	
ID	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**
A101	73.65	75.97	13.25	8.59	20.30	26.97	-3.25	-1.20	0.40	1.26	-1.50	-2.08
A103	72.55	75.43	13.30	8.80	23.45	28.03	-4.60	-0.87	0.70	1.50	-1.80	-2.15
B17	76.25	79.81	9.25	3.91	28.40	31.75	-9.15	-2.38	1.40	0.65	-2.40	-1.61
B30	80.70	80.32	7.20	4.10	21.05	29.38	-7.60	-4.21	0.35	0.75	-1.15	-1.32
C32	75.05	75.52	11.25	8.58	20.15	28.60	-3.40	-1.48	0.70	1.52	-1.50	-2.20
C35	67.10	79.88	17.40	3.75	22.80	32.73	-3.35	-3.18	1.25	0.63	-1.70	-1.34
C54	76.25	79.19	9.95	4.48	26.35	31.76	-8.75	-3.35	1.55	1.06	-2.40	-1.74
DM5637*B8	78.25	79.16	7.85	4.07	24.30	30.95	-7.65	-4.73	0.60	0.98	-1.20	-1.17
H45	75.45	78.67	11.95	5.70	21.50	29.14	-5.20	-3.05	0.25	0.93	-1.45	-1.69

Tetraploid wheat populations

Reduced Blackpoint Incidence

Three populations of plants prepared by Dr Hare between two mr and elite germplasm have been produced (F3) in 2005. These were evaluated for BPt susceptibility to identify plants having greater resistance than either parent in the 2006 field trials (n=490 plots). From two of these crosses about 20 lines were identified showing lowered BPt sensitivity which will be further developed in the ADWIP. Crosses were between lines 980086 (32%BPt) X 981151 (7%BPt); 981190 (14%) X 200903 (35%BPt); 980103 (12% BPt) X 201177 (35% BPt). There were 32, 122 and 74 plants obtained from these crosses, respectively for analysis. They were tested in the field in 2006 in replicated TH. All analyses were visual, for greater accuracy.
In cross 1 plants produced a range in BPt 20-35% with no lines lower than parent line 981151 (Figure 1). None of these will be pursued because their BPt levels are too high. In cross 2, the range in BPt was 16-56% with a few lines close to the lower parent line (Figure 2). These segregants will be further pursued. For cross 3, the range was 11-42% with several segregants showing promise for further work (Figure 3).

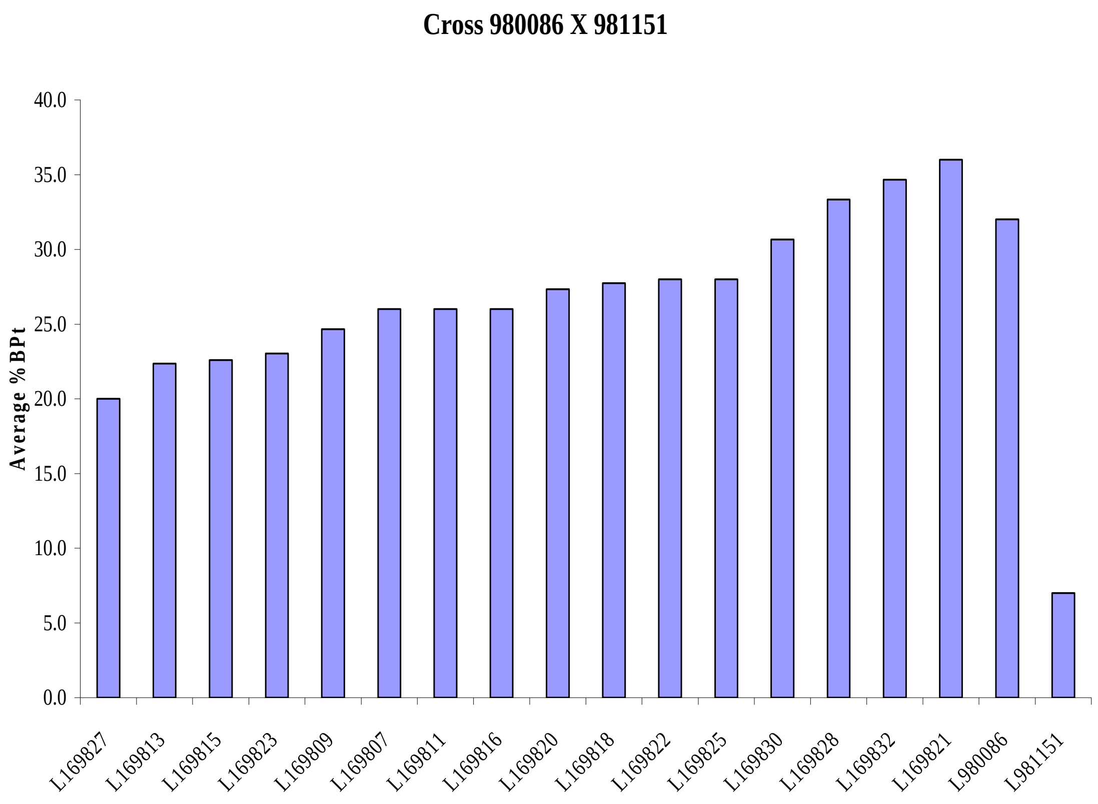


Figure 1 Distribution of Bpt incidence in cross 980086 x 981151

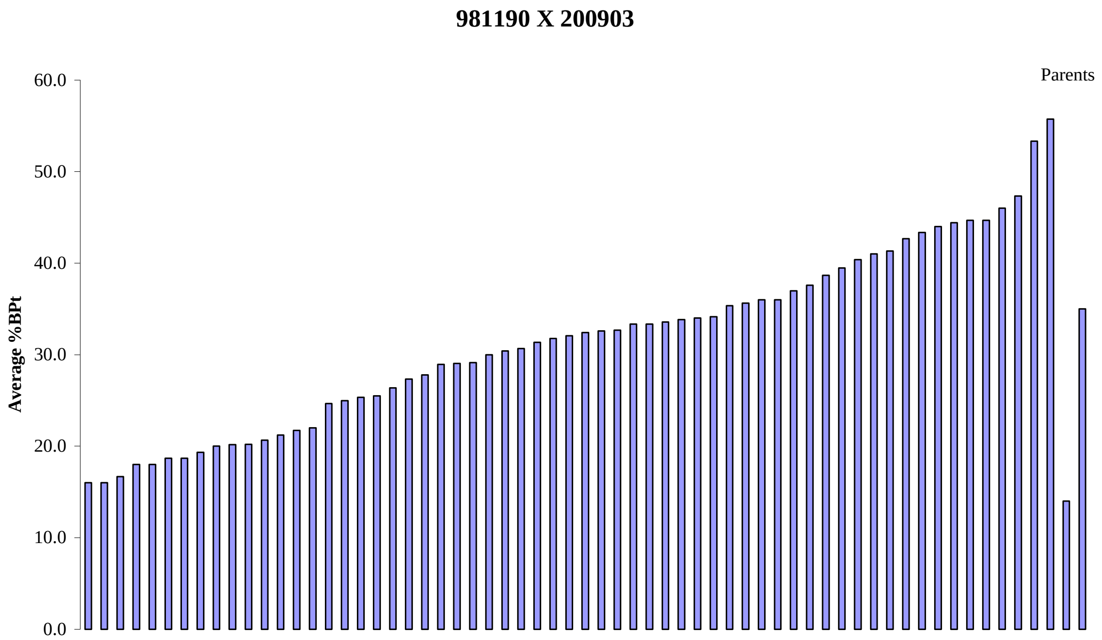


Figure 2 Distribution of Bpt incidence in cross 981190 x 2000903

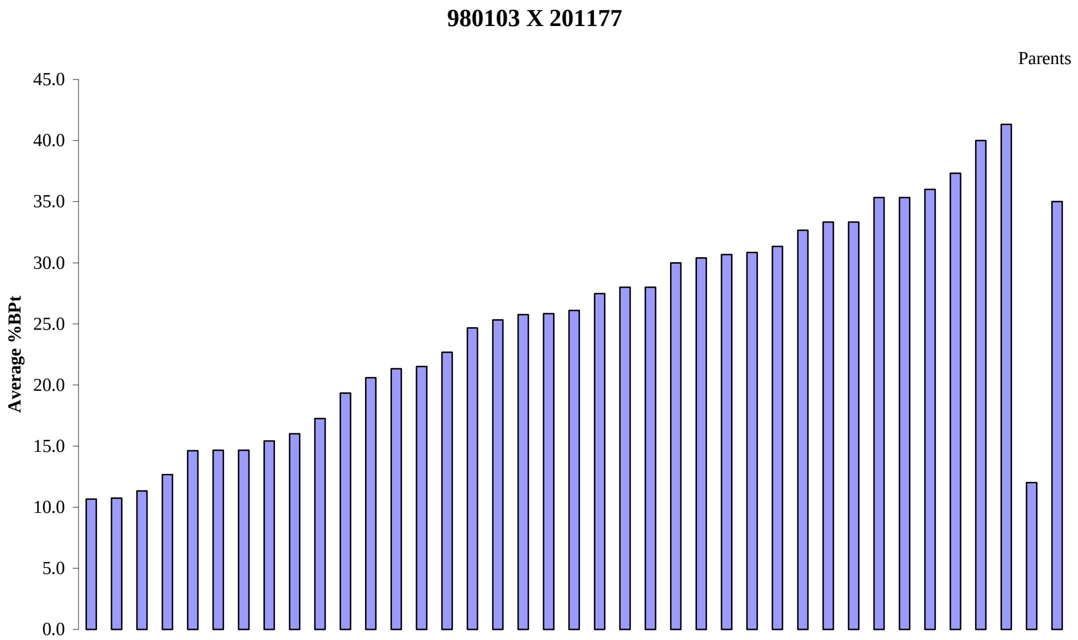
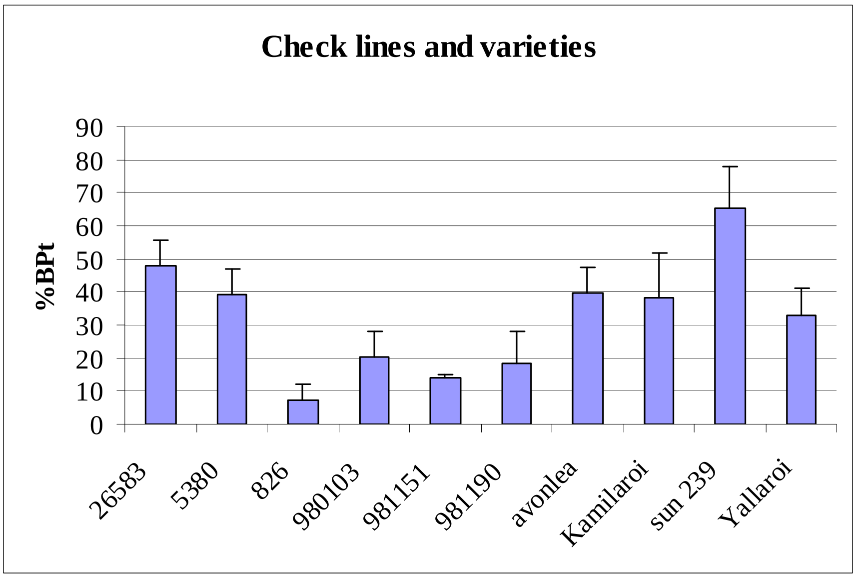


Figure 3 Distribution of Bpt incidence in cross 980103 x 201177

The check varieties and lines behaved as expected (Figure 4). Sun 239, which is a highly susceptible line, had the highest BPt. Yallaroi and Kamilaroi are also quite susceptible. Canadian supposedly mr resistant Avonlea was highly susceptible in this environment. Breeding lines used in crosses were low but the lowest was AUS826, a *T durum*.

Figure 4 Distribution of Bpt incidence in cross 981190 x 2000903



Several lines were found to have lower BPt than their parents and were given to Dr Hare for sowing in 2007. These samples will also be given to Dr Turner for backcrossing in 2008. The 2006 season was characterised by higher BPt levels than some previous years as shown by higher BPt % for the control and mr controls.
In addition crosses between mr and hs and another cross between mr and Bellaroi are also being developed using backcrossing by Dr Turner at PBI Cobbitty.
Material from both populations has been advanced to F3.

Developing variation in starch swelling power in durum wheat

Data produced at the 2000 IWGS by Nakamura et al found wide variation in amylose content up to 42% by their methods. All of the germplasm surveyed by that group was obtained by the University of Sydney and tested for starch amylose content using the iodine binding assay in Matthew Turner's lab. Several lines were identified with to possibly possess elevated levels. When the same seed was introduced into the AWCC and grown over the year, the resulting seed when assayed for amylose by either the iodine binding or the Megazyme method in Mike Sissons lab failed to show high levels.

Given the recent findings by Dr Turner that there was an association between amylose content and starch swelling power, [also see references Gianibelli et al 2005 Cereal Chem 82:321 and Sharma et al 2002 J Cereal Sci 35:287] we decided to make crosses between the previously identified lines by Dr Turner with elite durum. The crosses made were:

Bangasia 8628 X Bellaroi
Bangasia 8628 X 940955 breeding line
Italian 8870 X 970086
Italian 8870 X 970355
Italian 8870 940955
Italian 8870 X Bellaroi

F3 seed was harvested at Breeza NSW in Dec 2005 and evaluated for starch swelling power at Tamworth in early 2006. The distribution of SP across the various crosses is shown in the following diagrams (Figures 5-10). Control starches are Amylopectin (Sigma) SP ~30 and Hylon 7 SP ~4.8. There was a wide range in SP. In most crosses there were lines with much lower SSP than either of the parents. Lines having low SSP were identified and will be used in future work.

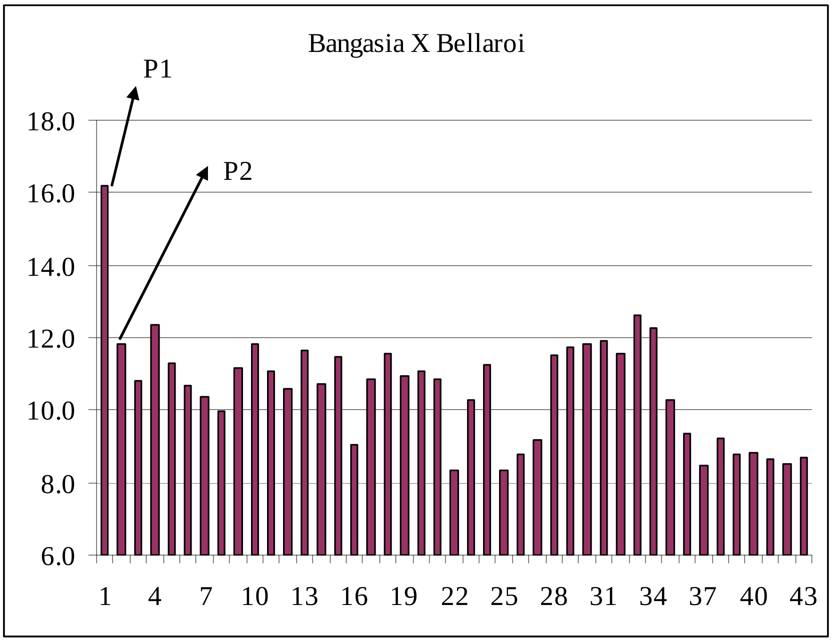


Figure 5 Distribution of starch swelling power in cross Bangasia x Bellaroi

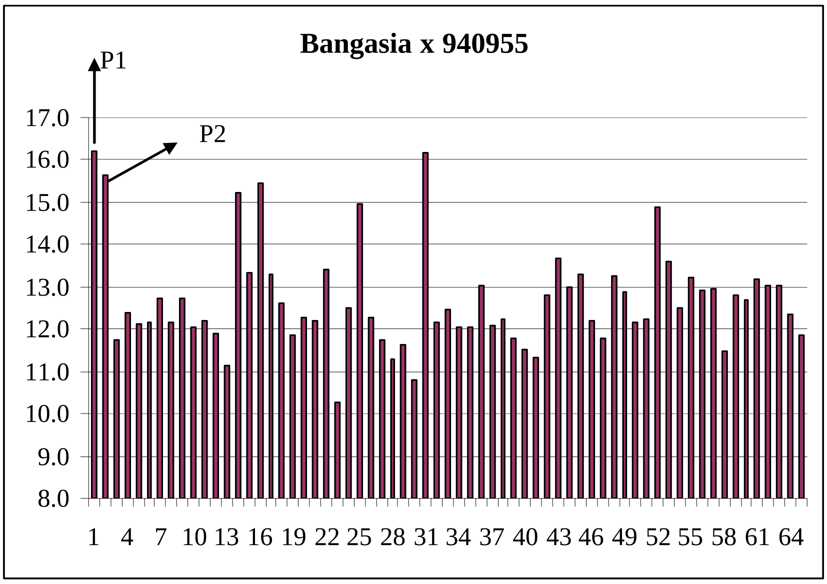


Figure 6 Distribution of starch swelling power in cross Bangasia x 940955

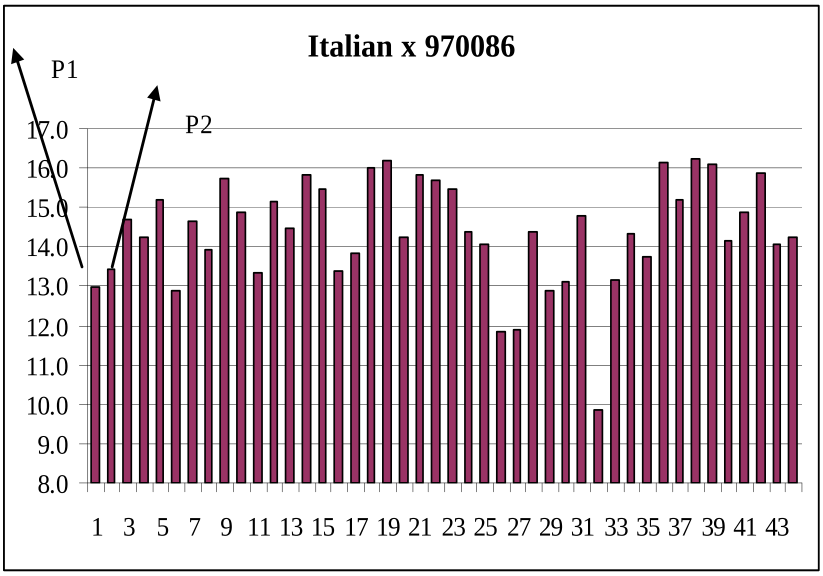


Figure 7 Distribution of starch swelling power in cross Italian x 970086

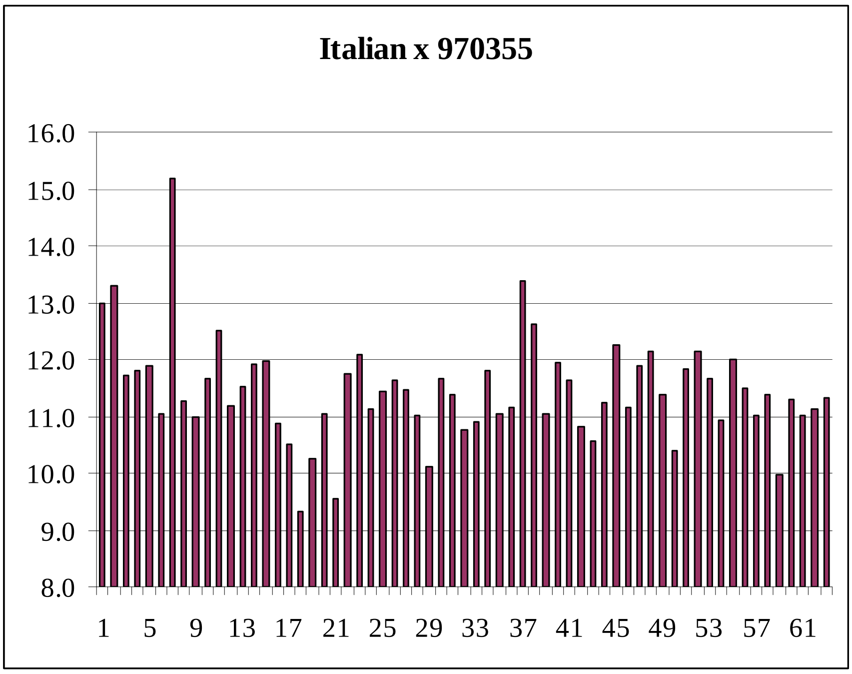


Figure 8 Distribution of starch swelling power in cross Italian x 970355

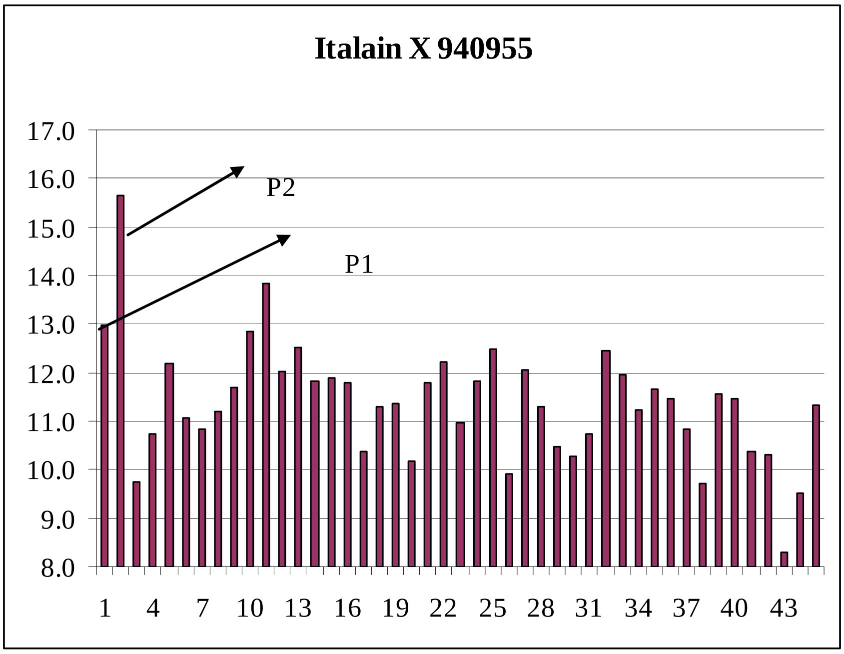


Figure 9 Distribution of starch swelling power in cross Italian x 940955

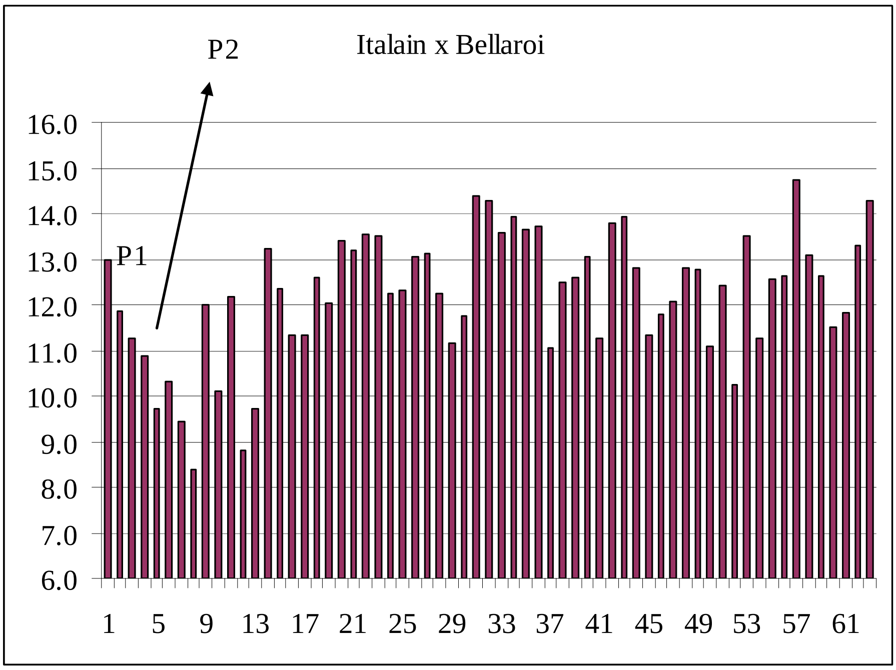


Figure 10 Distribution of starch swelling power in cross Italian x Bellaroi

Extremes of Starch Granule Size Distribution in durum wheat

Populations derived from a Yallaroi x Low b granule T. durum var dicocoides accession (20% b granules) and Yallaroi x high b granule T. durum var dicocoides accession (40% b granules) were generated and grown in a field environment at TAI. Starch granule size distribution was determined and selected lines possessing high and low extremes were identified.

The distribution of B-granule content in starches from lines derived from each cross are shown in figures 11 and 12. Some lines possessed a higher B-granule content than the high B granule parent but no lines were identified with lower B-granules than the low B-granule parent, 3810. Selected lines that possess extremes of b granule content are being topcrossed to Bellaroi.

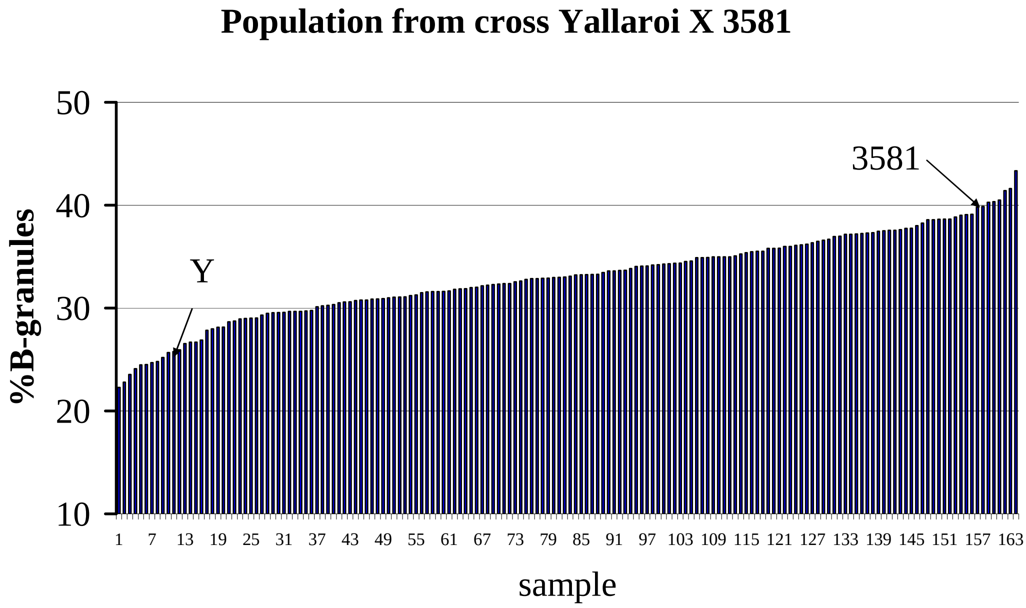


Figure 11 Variation in B-granule content of starches derived from 164 lines from the Yallaroi x 3581 (high B-granule content) population.

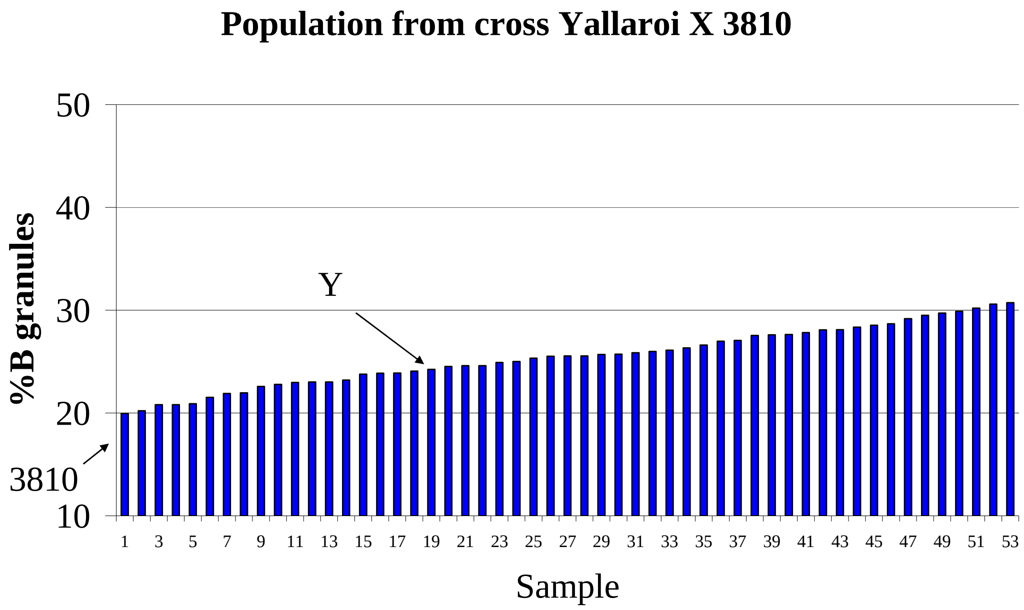


Figure 12 Variation in B-granule content of starches derived from 53 lines from the Yallaroi x 3810 (low B-granule content) population.

Starch swelling power can be manipulated by altering the amylose content in starch. In general, as amylose content decreases, SP increases in durum (Gianibelli et al 2005). Unpublished data in our lab. has found a negative correlation between B-granules and SP in hexaploid wheat. In the populations created here, there was a low correlation between %B-granules and SP (Figure 13).

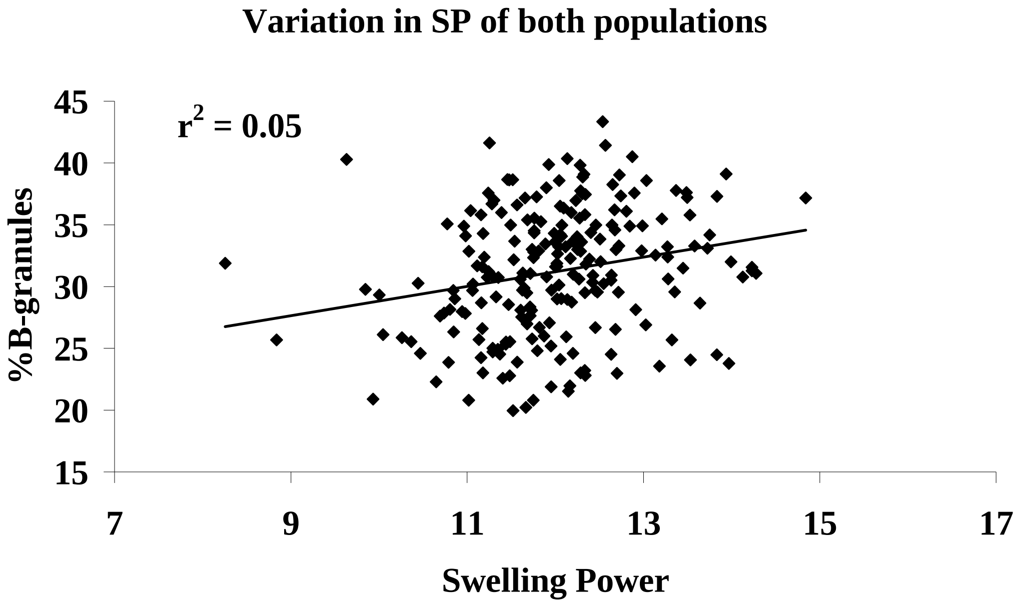


Figure 13 Relationship between %B-granules and starch swelling power in both populations.

Discussion

A number of elite materials that possess novel extremes were generated in the project. Some preliminary trialling of the most advanced material was conducted. It is recommended that the most promising of this material be trialled and subjected to quality testing.
Some populations that are not evaluated should be multiplied and evaluated in similar trial regimen. QTL mapping was performed in some of this material and markers that were associated with highly significant alleles should be applied in breeding selection.

Recommendations

Null PPO
The germplasm that was developed in this project possesses a range of PPO activities (low to null). Yield trialling, rust testing, further agronomic evaluation and quality testing is required if any of this material is to be released as a commercial cultivar.

Large grain size
The germplasm developed in this project that has large grain size is not of sufficient standard to warrant testing for release. However it should be used as a parent in a breeding effort to generate a large grained wheat cultivar.

Water Extractable Pentosans
The material that was generated in this project is not phenotyped yet. An effort is continuing to achieve this. It is expected to be phenotyped by the end of 2008. Further evaluation will be required after the material has been phenotyped.

Extremes of Starch Granule Size Distribution

This material has to be subjected in biscuit quality tests to evaluate its usefulness. Alternatively it should be used in breeding efforts as a parent.

Sprouting Tolerance

The selected material from the DM x H45 population is in most cases not tolerant to sprouting. However two lines B17, and A101 should be evaluated further for the trait because they appear to be very sprouting tolerant. All of the selections should be further evaluated in breeding trials and subjected to rust and quality testing.

Tetraploid wheat populations

Extremes of Starch Swelling Power

The identified material needs to undergo further rounds of crossing with other diverse sources of the trait. Once very low swelling power wheats are developed GI testing and breeding to generate cultivars will have to be performed.

Extremes of Starch Swelling Power Granule Size Distribution

The material that possesses high or low extremes of b granule content needs to be improved agronomically by breeding. Concurrent work to demonstrate it usefulness would be desirable.

Reduced Blackpoint Incidence

The identified material needs to undergo further rounds of crossing with other diverse sources of the trait. Once very low Bpt wheats are developed breeding to generate cultivars will have to be conducted.

References

American Association of Cereal Chemists. 2000. Approved methods of the AACC, 10th ed. The Association: St. Paul, MN.

Bariana HS, Parry N, Barclay IR, Loughman R, McLean RJ, Shankar M, Wilson RE, Willey NJ and Francki M (2006). Identification and characterization of stripe rust resistance gene Yr34 in common wheat. Theoretical and Applied Genetics **112**, 1143-11488.

Bernier AM and Howes NK (1994). Quantification of variation in tyrosinase activity among durum and common wheat cultivars. Journal of Cereal Science **19,** 157-159.

Gianibelli MC, Sissons MJ and Batey IL (2005). Effect of source and proportion of waxy starches on pasta cooking quality. Cereal Chem. **82**, 321-327.

McCaig TN, Fenn DYK, Knox RE, DePauw RM, Clarke JM and Mcleod JG (1999). Measuring polyphenol oxidase activity in a wheat breeding program. *Canadian* Journal of Plant Science **79,** 507-514.

Sharma R, Sissons MJ, Rathjen A J and Jenner CF (2002) The Null-4A Allele at the waxy locus in durum wheat affects pasta cooking quality. J. Cereal Sci. **35**, 287-297.

Stoddard, FL (1999) Survey of starch particle-size distribution in wheat and related species. Cereal Chem. 76: 145-149.

Wellings CR and Bariana H (2004) Assessment scale for recording stripe rust responses in field trials. Cereal Rust Report **2,** 1-2.

Appendix 1 Hexaploid wheat germplasm

Project	Cross			Lines		Target
4.3.8	DM5637*B8 x H45	100	population	189		Sprouting tolerance
4.3.8	Lang xPPO1		population	140		Null PPO YAN
4.3.8	Qalbis xPPO1			210		Null PPO Soft
4.3.8	Goldmark X DM5637*B8			110		High soluble pentosan and water absorption/ high milling yield
4.3.8	Angas x Qalbis		mt706	36		Low soluble pentosan, biscuit
4.3.8	Angus x Bowie		asad121	1		Low soluble pentosan/ water absorption, cracker
4.3.8	Qalbis x Syn7		mt704	31		Low soluble pentosan, biscuit
4.3.8	Goldmark x Chara	40	mt705	25		High soluble pentosan and water absorption/ high milling yield
4.3.8	Goldmark x Lang	140	asad131	1		High soluble pentosan and water absorption/ high milling yield
4.3.8	More x Kukri		mt708	150		High soluble pentosan and water absorption
4.3.8	Cacades x Lang		mt715	36		Blackpoint
4.3.8	Lang x Cascades		mt710	1		Blackpoint
4.3.8	Lang x L3		mt711	28		Large grain Prime hard
4.3.8	Lorikeet x L3		mt703	20		Large grain, WSN
4.3.8	DM5637*B8 X PPO2	140	asad21	1		Null PPO, sprouting tolerance bread/noodle
4.3.8	Kukri x DM5637*B8		mt701,mt713	1		Sprouting tolerance
4.3.8	DM5637*B8 x L1	155	asad61	1		Sprouting tolerance, large grain
4.3.8	Kukri x Chara		mt714	28		Southern wheat, Glu 1b overexpression
4.3.8	Syn57 x Lang		mt712	6		Head scab
4.3.8	Syn110 x Sunco		mt709	172	(22 DH + 150f3)	included in the ARC linkage grant with longreach

Appendix 2 Tetraploid wheat germplasm

Project	Cross		Lines		Target
4.3.8	980103 x Bellaroi	200	150	f3	blackpoint
4.3.8	MS4105 x Bellaroi	200	150	f3	blackpoint
4.3.8	980086 x 981151	selns		f3	blackpoint
4.3.8	981190 x 200903	selns		f3	blackpoint
4.3.8	980103 x 201177	selns		f3	blackpoint
4.3.8	Bangasia x Bellaroi	selns		f3	SSP
4.3.8	Bangasia x 940955	selns		f3	SSP
4.3.8	Italian x 970086	selns		f3	SSP
4.3.8	Italian x 970355	selns		f3	SSP
4.3.8	Italian x 940955	selns		f3	SSP
4.3.8	Italian x Bellaroi	selns		f3	SSP