Progress in Developing a Hulless Barley Industry

Amanda Box[1], **Jennifer Washington[2]** and Jason Eglinton[1]

[1] School of Agriculture and Wine, Faculty of Sciences, Waite Campus, University of Adelaide, Glen Osmond, 5064, South Australia, Australia. Web address: www.adelaide.edu.au. Email: amanda.box@adelaide.edu.au
[2] Australian Stem Cell Centre, School of Molecular and Biomedical Sciences, University of Adelaide, 5005, South Australia, Australia.

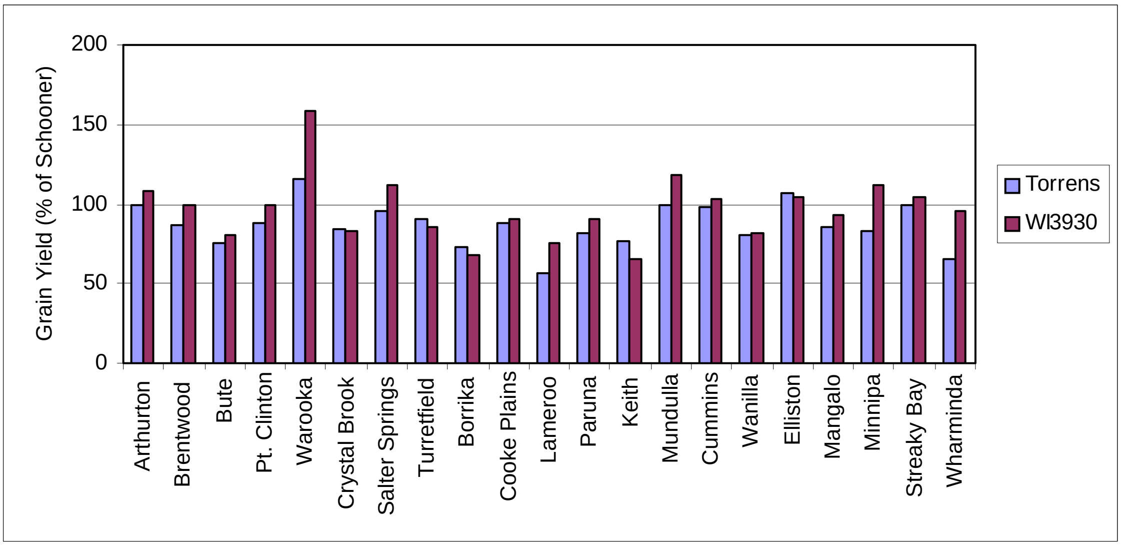
Introduction:

In September 1988, the Cereal Chemistry Division of the RACI hosted the 'Alternative End Uses of Barley' workshop in Adelaide. This workshop generated considerable interest for local animal feed compounders, where barley breeding programs at the University of Saskatchewan, Saskatchewan and the Field Crop Development Centre, Alberta released two hulless barley cultivars for their local growers. Consequently, hulless barley breeding at the Waite Campus was initiated in 1989 and the major objective is to develop hulless types for the following end uses:
1. Low beta-glucan feed types for monogastric animals, 2. Food industry (waxy and high amylose), 3. Various industrial and commercial uses (eg. low and high amylose), and 4. Malting and brewing industries.
The major sources of hulless germplasm used at the Waite Campus are from Canada and Mexico with minor inputs from North America, Europe and Japan. A large number of these lines are poorly adapted to many agro-ecological regions in Australia. They are either too tall, have poor straw strength, poor head retention, have maturity problems, very low yielding and have small grain. Therefore, our biggest challenge has been to develop hulless lines that are more comparable to Australian locally adapted cultivars. As a result, the South Australian Barley Improvement Program (SABIP) released Torrens in 2001 with a national, co-ordinated approach as a first step to supporting similar developments observed in the Canadian pig industry. Compared to older hulless cultivars, Torrens has improved grain yield, agronomy and feed quality. The SABIP has now also targeted the development of hulless barley adapted to higher rainfall areas. Pure seed production of the hulless feed barley line WI3930 commenced in 2005, with potential release in 2006. WI3930 has improved grain yield and feed quality compared to Torrens.
In current overseas markets, the primary use of hulless barley is in monogastric feed rations, but future uses could include human food industries and the malting and brewing industries. Despite their potential for low insoluble fibre, high digestibility (beneficial to the feed industry) and easier preparation for human food products, hulless barley remains a curiosity within Australia. What will it take to develop a viable industry around hulless barley cultivars in Australia? Market development and solving processing problems in food and malt applications is a key strategy in successfully launching hulless barley as a profitable field crop.
This paper will highlight the improvements we have made to new hulless cultivars and germplasm with respect to yield potential and agronomic characteristics, and the markets that will benefit from the use of this barley type.

Overall Agronomic Performance:

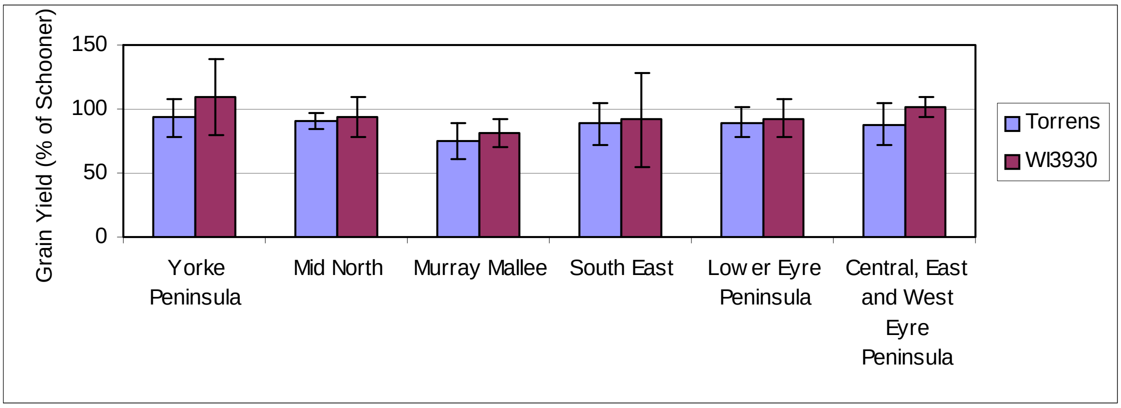
Yield Disadvantage:
A large number of introduced hulless lines are poorly adapted to many agro-ecological regions in Australia. Therefore, our biggest challenge has been to develop hulless lines that are more comparable to Australian locally adapted cultivars. In year 1992, Namoi was released as an Australian hulless cultivar, but suffered from poor yields. As a result, Torrens was released in 2001 with a strong focus on market development for hulless barley. Torrens averages 4% higher yields than Namoi, with higher yield potential in most agro-ecological regions of South Australia. However, its average yield potential compared to Schooner is 92%. The SABIP has now also targeted the development of hulless barley adapted to higher rainfall areas. Pure seed production of the hulless feed barley line WI3930 commenced in 2005, with potential release in 2006. WI3930 has improved grain yield and feed quality compared to Torrens. Figure 1 demonstrates the improved yield potential of WI3930 compared to Torrens in SARDI Advanced Trials grown in South Australia in 2004 (21 sites, 4 replicates).

Figure 1. Grain yield performance for Torrens and WI3930 expressed as a percentage of Schooner. These results are from the 2004 SARDI Advance Trials planted at 21 locations around South Australia.



Yield Stability and Adaptation:
Torrens and WI3930 are better adapted to the agro-ecological zones that have medium to high annual rainfall (Yorke Peninsula, Mid North, South East and Eyre Peninsula) as shown in Figure 2. In addition, WI3930 averaged 7% higher yields than Torrens in all districts, with best performances in the Yorke Peninsula and Central, Eastern and Western Eyre Peninsula districts. Lower grain yields for Torrens and WI3930 were observed in the Murray Mallee district, where the lighter, less fertile soils may be contributing factors.

Figure 2. Grain yield performances for Torrens and WI3930 expressed as a percentage of Schooner for the different agro-ecological zones of South Australia. These results are from the 2004 SARDI Advanced Trials planted at 21 locations around South Australia.



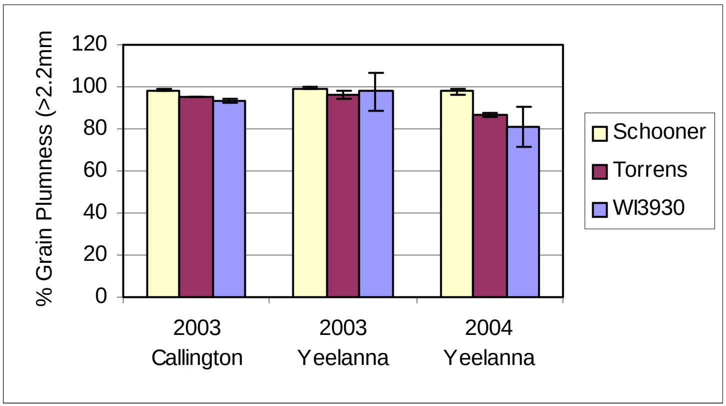
Lodging and head loss:
A large number of introduced hulless lines from Canada and Mexico have the propensity to be very tall resulting in severe lodging, stem break and head loss, all culminating in up to 50% reduction in grain yields. To reduce the severity of these negative traits, the SABIP has been actively seeking and using barley germplasm that is semi-dwarf in stature, resulting in the development of WI3930. WI3930 has a semi-dwarf habit and is lodging, stem break and head loss resistant. Whereas, Torrens has a medium plant height and is susceptible to head loss but has better resistance to lodging and stem break compared to Schooner (data not shown).

Grain Plumpness and 1000 Kernel Weights:
A major objective of the SABIP is to enhance the profitability of hulless barley for the feed industry. This is achieved by developing hulless types with improved and stable grain size and increased 1000 kernel weights.

1. Grain Plumpness (>2.2mm (%))

Torrens, WI3930 and Schooner were grown in three replicated trials at Yeelanna, Eyre Peninsula, South Australia during 2003 and 2004, and Callington, Upper Murray Mallee, South Australia during 2003. 100 gram samples were cleaned and screened over a 2.2 mm screen using Sample Cleaner Model SLN 3, Rationel Kornservice, Denmark. The results indicate that both Torrens and WI3930 have smaller grain than Schooner (Figure 3). However, the 2003 season was more favourable for plumper grain than 2004, when drier conditions were experienced during grain filling (September – October period). This trend is reflected in the 17% lower grain plumpness of WI3930 compared to Schooner in Yeelanna 2004. This can be explained by WI3930 having a later flowering time than Schooner, making WI3930 unable to avoid flowering and grain filling during the drier Spring months. Similarly, Torrens had an 11% decrease regardless of comparable maturities with Schooner. This trend was also reflected in 2003 Callington, with Torrens having 2% and WI3930 having 5% lower grain plumpness than Schooner. This could be explained by the lighter, less fertile soils observed at Callington. Such an environment would favour the maturity and adaptation of Schooner and Torrens, rather than WI3930.

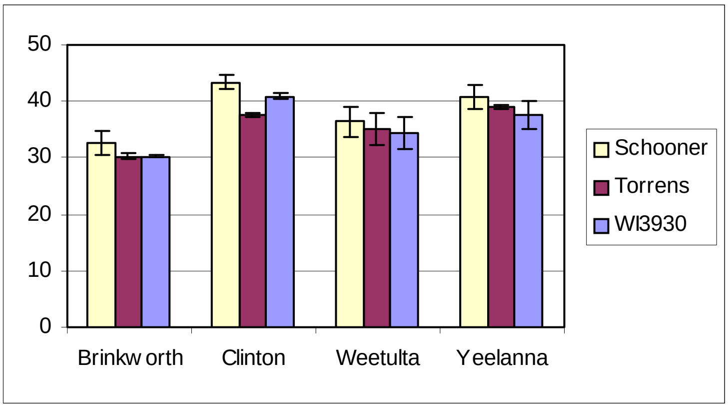
Figure 3: Grain plumpness performance for Torrens, WI3930 and Schooner grown at three locations in South Australia during 2003 and 2004.



2. 1000 Kernel Weights (g)

Torrens, WI3930 and Schooner were grown in three replicated trials at four locations across South Australia (Brinkworth, Clinton, Weetulta and Yeelanna) during 2004. Samples were cleaned and screened over 2.2mm screen and 1000 grains were counted using a Contador Pfeuffer Seed Counter and weighed. The results indicate that both Torrens and WI3930 have lower grain weights for all four sites when compared to Schooner (Figure 4). This difference couldcan be attributed toexplained by the presence of an attached husk in the Schooner samples.

Figure 4: 1000 Kernel Weights for Torrens, WI3930 and Schooner grown at four locations in South Australia during 2004.



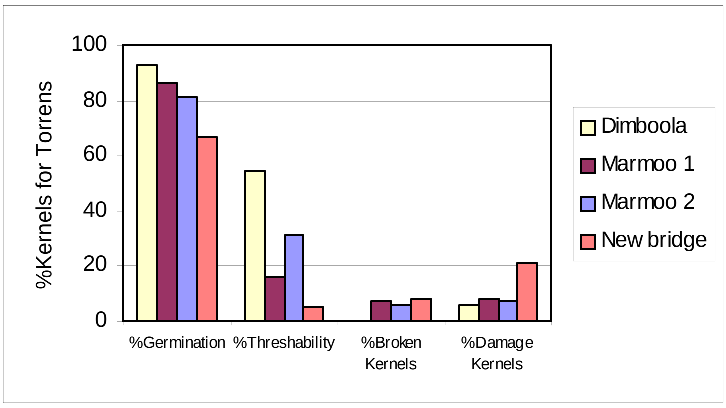
Harvest Damage and its Effect on Germinative Capacity:

Special consideration needs to be given when harvesting hulless barley to prevent excessive damage to the grain. Because of the exposed embryo, it is important to leave some husk on during harvesting. This will protect the embryo from mechanical damage and make it viable for >90% germination for seed and malting purposes. If the end use is for food usage, then the additional husks can be removed using an oat-dehuller. For animal feed the embryo damage is less of a problem however, broken kernels in feed samples needs to be monitored, ensuring that it be kept to a minimum. To highlight the impact harvest damage has on hulless barley germination, we analysed the % germination, threshability (% husks left intact) and the % broken and damaged kernels in commercial samples of Torrens and SABIP advanced yield trials.

1. Commercial production of Torrens in 2002.

In 2002 Torrens samples were requested from four growers for germination analysis. 100 kernels were accurately counted using Contador Pfeuffer Seed Counter, placed in a petri dish with 4ml of R.O. water and put in an incubator set at 20°C. Germinated kernels were counted and discarded at 24 hours, 48 hours and 72 hours. Percentage of germination was calculated and the remaining ungerminated kernels were assessed for damage to the embryo. In addition, broken kernels were assessed and counted, along with kernels that still had the husk attached (threshability). The results in Figure 5 indicate a positive relationship between high germination rates and retaining a high percentage of husk content on the kernels (indicative of the producer at Dimboola) to protect the embryo during the germination process. On the other hand, the crop produced at Newbridge had low percentage of husk content, leading to higher levels of broken and damaged kernels resulting in lower germination percentages.

Figure 5: The effects of harvest damage on the grain quality of four commercial crops of Torrens in the 2002 season.



2. SABIP Advanced Yield Trials

Torrens, WI3930 and Schooner were grown in three replicated trials at four locations across South Australia (Brinkworth, Clinton, Weetulta and Yeelanna) during 2004. Germination (%), threshability (%), damaged kernels (%) and broken kernels (%) were assessed as described above. The results in Figures 6a – 6d indicate that Schooner had the highest germination rates and the lowest levels of harvest damage at all locations evaluated, most likely due to the added protection of the husk. The lowest germination rates and highest levels of harvest damage for Torrens (13% lower germination) and WI3930 (10% lower germination) were observed at Clinton. This could be attributed to the aggressive harvest techniques as indicated by the low threshability of these hulless genotypes. At the other three sites, greater than 90% germination was observed in the hulless genotypes.

Figure 6a and 6b: % Germination and Threshability performances for Schooner, Torrens and WI3930 across four SA locations during 2004.

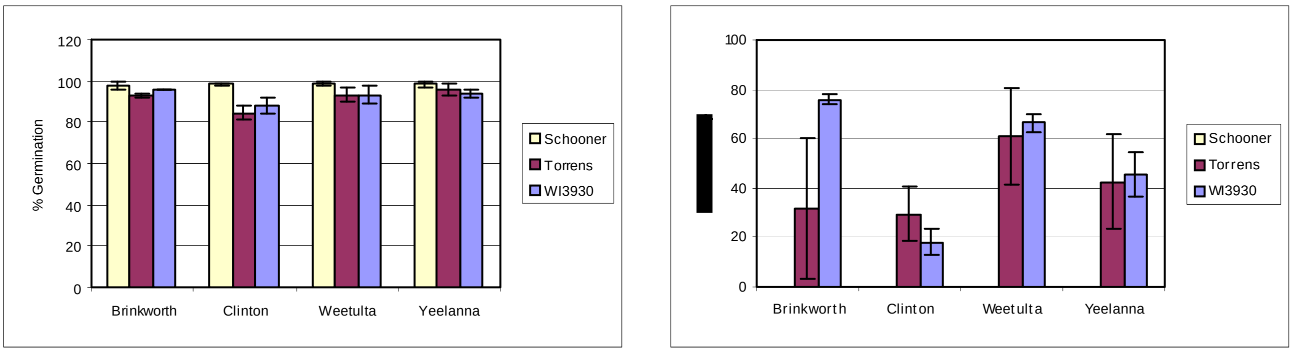
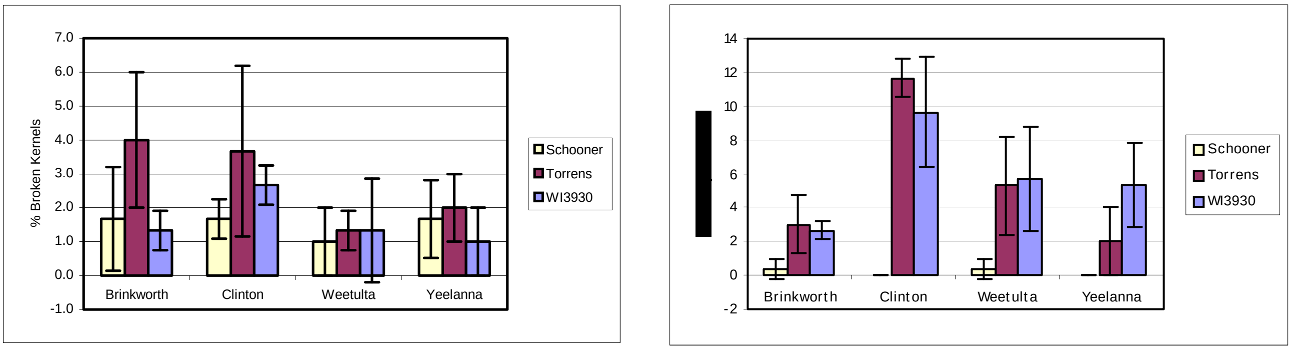


Figure 6c and 6d: % Broken and Damaged Kernels for Schooner, Torrens and WI3930 across four SA locations during 2004.



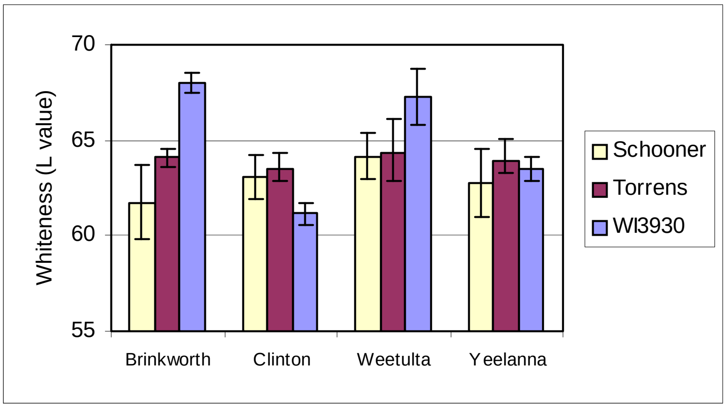
Kernel Colour:

Kernel colour has no effect on feed value but the product must be aesthetically pleasing to the grower and the purchaser of the product for it to be successfully marketed, especially for food uses. We have observed genetic variation in kernel colour with earlier crosses Galleon/CIMMYT 42002 and Galleon/Richard and the worst crosses having Chebec as a parent, for example, Chebec/SB85216 and Nudinka/Chebec.

More recently, we have been using germplasm from Canada (for example, TR118) and Japan (for example, Nasu nijo) and the progeny are being assessed in early generations trials in 2005, with the first yield trials to be assessed in 2007.

Whiteness (L value) of grain samples were measured with a Minolta colorimeter using the CIE L*a*b colour score. The results indicate the best locations for producing the whitest grain are Brinkworth and Weetulta, with Yeelanna producing the lowest L values (Figure 7). It is difficult to compare whiteness values between covered and hulless genotypes due to the component of the grain being measured, for example, husk in covereds and aleurone in hulless. The issue of threshability in hulless genotypes further complicates this. However, colour differences may be explained through the spike morphology. The developing hulless grain can often get too large for the surrounding palea and lemma. Consequently, there can be a gap of a few millimetres between the palea and lemma and so the grain can be exposed resulting in 'sunburn'. It is a problem that has not been observed in wheat, triticale or oats. The results demonstrate the large environmental influence on kernel colour.

Figure 7: Colour measurement (L value) for Torrens, WI3930 and Schooner grown at four locations in South Australia during 2004.



Animal Feed Evaluation:

At present the use of feed barley in monogastric diets is governed by the cost per nutrient (for example, digestible energy (DE)). Improved grain yields and a wider area of production will considerably reduce the cost and be the most appropriate short-term objective for plant breeders (1). In the longer term, to optimise animal production, we need to define the variation in the available energy and amino acid composition of feed barley and to understand those factors that influence nutritive value.

Appreciating that the primary use of hulless barley in Canada is in pig production, we evaluated four Australian barley genotypes in four animal feed assays – acid-detergent fibre (ADF) (%), *in vitro* digestible energy (DE) (MJ/kg), *in vitro* digestible dry matter (DDM) (%) and amino acid composition. In all four assays, the hulless genotypes are generally superior to Schooner and Barque (Tables 1 and 2), i.e. lower ADF and generally higher DE and DDM. The amino acid composition was particularly impressive for WI3930 compared to Schooner. For all indispensable amino acids, WI3930 produced a range between 6% (Aspartic Acid) and 27% (Histidine) higher than Schooner. Furthermore, WI3930 had a 10% higher level of lysine than Schooner. Overall these chemical analyses are encouraging but more research into *in vivo* pig digestible energy could provide additional information as to the animal's ability to utilise these nutrients during digestion, absorption and metabolism and, ultimately, how they behave in the presence of nutrients from other feed ingredients. This additional research is necessary before hulless barley cultivars could be launched confidently into the Australian pig industry.

Table 1. Results for two hulless barley genotypes compared to Schooner and Barque grown in 2004 in South Australia evaluated in three animal feed assays, acid-detergent fibre (ADF), *in vitro* digestible energy (DE) and *in vitro* digestible dry matter (DDM).

Barley Genotype	ADF (% of dry matter)	DE (MJ/kg)	Dry Matter (%)
Schooner (covered)	4.90	13.00	88.40
Barque (covered)	4.50	13.20	88.80
Torrens (hulless)	4.30	13.3	88.60
WI3930 (hulless)	4.40	13.40	88.80

Table 2. Results for two hulless barley genotypes compared to Schooner and Barque grown in 2004 in South Australia evaluated for indispensable amino acid composition.

Amino Acids g/100g	Schooner	Barque	Torrens	WI3930
Aspartic Acid	0.61	0.49	0.59	0.65
Threonine	0.33	0.28	0.33	0.38
Glutamic Acid	2.80	2.43	2.89	3.61
Glycine	0.35	0.29	0.35	0.39
Alanine	0.37	0.32	0.37	0.41
Isoleucine	0.35	0.30	0.33	0.41
Leucine	0.73	0.62	0.71	0.85
Lysine	0.38	0.31	0.38	0.42
Histidine	0.22	0.20	0.24	0.28
Arginine	0.51	0.42	0.45	0.59
Proline	1.08	0.93	1.12	1.37

Human Food Evaluation:

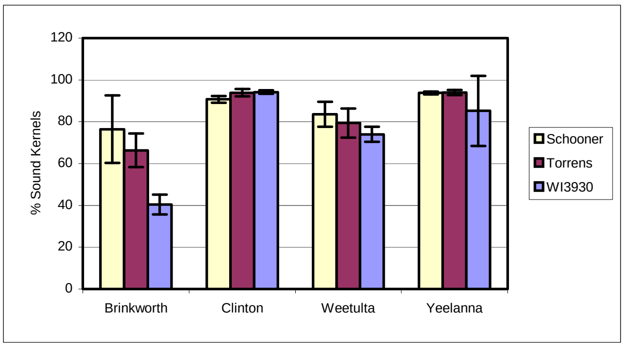
In Western countries, barley has traditionally been used in malting and as animal feed. For many years its potential within the human food industry was ignored. However, this is changing as dietary fibre is identified as being an important component of the human diet. Interest is focused on the nutritional potential of hulless barleys, in particular their soluble fibre and more increasingly, their novel starch composition, and their ability to lower blood cholesterol and prevent diseases of the large bowel including colon cancer.

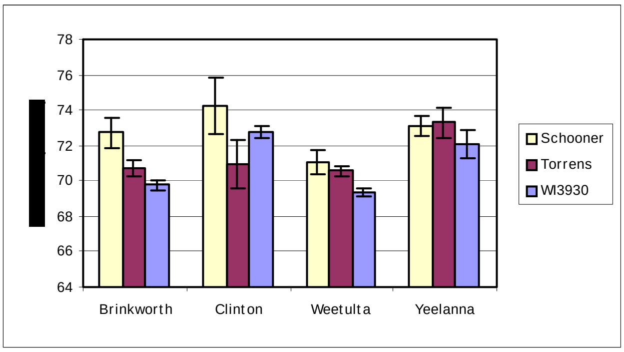
Barley is still used in many countries in traditional diets such as miso, shochu and finely pearled barley as a rice extender in Japan. In Korea, barley is the second most important food crop after rice and is used in several ways: 1. Pearled barley as a rice extender, 2. Pearled barley inoculated with *Aspergillus* sp. for the production of soy paste and soy sauce, 3. Roasted barley used as a tea or coffee substitute, and 4. Wheat-barley flour mixtures used for making breads, biscuits, cakes and noodles. In the West Asia-North Africa region, barley is consumed as pearled barley in soups, flour in flat breads and ground grain in porridge. However, much research still needs to be done on barley and its use in Western countries: functionality, taste and appearance, the behaviour of the barley bran and flour under the different conditions of processing, food preparation and preservation, product development, and consumer acceptability (2). The potential role of hulless barleys in these markets is still largely unknown but the potential does exist.

40 grams of were de-hulled using a laboratory scale oat de-huller. The de-hulled samples were pearled to remove 20% (hulless genotypes) and 35% (Schooner) of kernel, using a Satake grain-testing mill, model TM-05. The time of pearling varied between 2 and 7 minutes. The sound kernels were calculated as a percentage of the whole pearled grain above a 2.0mm screen.

The overall best performing location for % sound kernels after pearling was Yeelanna (averaging 91% over three genotypes), with the worst performing being Brinkworth (averaging 56%). Brinkworth was a low yielding location with high screenings, resulting in low % sound kernels (Figure 8a). In general, the averaged pearled grain colour is 2% lower for the two hulless genotypes compared to Schooner. At Yeelanna pearled grain colour was not significant between Schooner, Torrens and WI3930. Based on this preliminary data for sound kernels, germination and 1000 kernel weight, the better location for producing WI3930 for pearling classification would be Clinton, Yorke Peninsula.

Figure 8a and 8b: % Sound Kernel analysis and Pearled grain colour (L-value) for Torrens, WI3930 and Schooner grown at four locations in South Australia during 2004.





Conclusions:

The major sources of hulless germplasm used at the Waite Campus are from Canada and Mexico with minor inputs from North America, Europe and Japan. A large number of these lines are poorly adapted to many agro-ecological regions in Australia. They are either too tall, have poor straw strength, poor head retention, maturity problems, very low yielding and small grain. Therefore, our biggest challenge has been to develop hulless lines that are more comparable to Australian locally adapted cultivars. As a result, the South Australian Barley Improvement Program (SABIP) released Torrens in 2001 with a national, co-ordinated approach as a first step to supporting similar developments observed in the Canadian pig industry. Compared to older hulless cultivars, Torrens has improved grain yield, agronomy and feed quality. The SABIP has now also targeted the development of hulless barley adapted to higher rainfall areas. Pure seed production of the hulless feed barley line WI3930 commenced in 2005, with potential release in 2006. WI3930 has improved grain yield, foliar disease resistance and feed quality compared to Torrens.

In this paper we have compared advanced germplasm Torrens and WI3930 to Schooner but the same breeding principles have been applied to the development of other hulless germplasm throughout all the stages of the program. The objectives of the SABIP are to improve yield, stability and adaptation, straw strength, reduce lodging, stem break and head loss, improve grain plumpness, decrease the effects of harvest damage on germination rates and make selections for improved kernel colour.

More recently, the SABIP has been focussing on developing germplasm that is targeted to the animal feed and human food industries. Hulless barley also has potential in the malting and brewing industries. Preliminary research with AusMalt, Coopers (3) and Bakery Hill Distillery has been undertaken. Hulless barley has shown potential in the production of malt extract for beer and whisky. The challenge with this germplasm development has been in assessing those breeder's lines that offer a wide variety of quality traits. In addition, the requirements of the respective industries are constantly changing and reviewing their objectives. However, we have shown results for Torrens and WI3930 that indicate potential for a diverse range of industries including feed and food. The future for the development of hulless barleys is looking very favourable.

References:

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