Wheat Traits, Summary, and Discussion Document

Background

Prof Don Marshall and Ross Fellowes undertook a review of wheat traits in relation to pre-breeding and breeding objectives. Their findings were first presented to members of the Australian Winter Cereals Pre-breeding Alliance in July 2006, and their report was finalised in September 2006.

Since then there has been critical examination of their views, and extensive discussion including workshops held in 2007 on specific traits areas. These were the Workshop on Pre-breeding for Better Performance under Drought (Canberra, 5-6 September 2007) and the Workshop on Pre-breeding for Wheat Quality (Melbourne, 19-20 November 2007).

The feedback on the Marshall and Fellowes Report, received both formally and informally, has been incorporated into this summary document.

The list of biotic and abiotic traits has been endorsed by the Steering Committee of the Pre-Breeding Alliance. In contrast, a list of wheat quality traits requires further discussion taking into account feedback from participants of the wheat quality workshop and from industry stakeholder organisations.

Once finalised and endorsed by the Pre-Breeding Alliance the list of priority traits will provide the basis for determining future investments by the GRDC and Alliance members in wheat pre-breeding research.

The traits are listed in alphabetical order, so their position in the list bears no necessary relation to priority.

List of Traits:

Biotic

- ⇒ **Crown rot**
- ⇒ **Leaf rust**
- ⇒ **Root Lesion Nematode, *Pratylenchus neglectus***
- ⇒ **Septoria tritici blotch (STB)**
- ⇒ **Staganospora (syn. Septoria) nodorum blotch (SNB)**
- ⇒ **Stem rust**
- ⇒ **Stripe rust**

Abiotic

- ⇒ **Drought tolerance/ water use efficiency**
- ⇒ **Frost tolerance**
- ⇒ **Salinity tolerance**

Quality

- ⇒ **Defect Elimination**
- ⇒ **Late Maturity Alpha-amylase (LMA)**
- ⇒ **Pre-harvest sprouting**
- ⇒ **Dough Mixing Characteristics (Strength, extensibility, mixing time)**
- ⇒ **Flour water absorption for bread manufacture**
- ⇒ **Milling yield**
- ⇒ **Quality for Asian markets**
- ⇒ **Noodle manufacture**
- ⇒ **Bread making quality**

Biotic:

Crown rot

Crown rot is a significant problem in NNSW and southern Queensland, and is considered by breeders to be a high priority for southern as well as northern regions. The disease has proved to be difficult to control and has apparently increased in importance over the last decade, in part owing to changes in tilling practices. Research has been well supported, and the GRDC has in place a Crown Rot Initiative with projects on disease management as well as those seeking genetic solutions. Limited resistance is available in cultivated wheats and while differences are evident between varieties, screening techniques are time consuming, expensive and of limited reliability.

Recent research has yielded exciting results in terms of potential new sources of resistance and improved laboratory screening protocols for this disease, including the application of molecular markers. There is a need for continuing research to confirm these results and to develop efficient and effective screening techniques and new sources of resistance/tolerance if the disease is to be controlled genetically.

Leaf rust

The issues for leaf rust are similar to those for stem and stripe rusts, however there has been less success in controlling leaf rust compared to stem rust using genetic resistances. This is attributed to leaf rust usually being regarded as a less serious threat compared to stem rust and stripe rust, and also to the fact that new races occur on a regular basis. Consequently, as with stripe rust, emphasis is now being given to combinations of minor genes for resistance, which are expected to be more durable. Research is coordinated through the National Cereal Rust Control Program, and effective sources of resistance are available to all breeding programs.

Root Lesion Nematode, *Pratylenchus neglectus*

Pratylenchus neglectus is more common in southern Australia while *P.thornei* is more common in the northern wheat belt although both species can occur together

throughout wheat growing regions. There are difficulties in accurate and cost-effective phenotyping, and economic losses due to *P. neglectus* may be underestimated. The identified and available sources of resistance and tolerance to *P.thornei* do not appear to be effective in controlling *P.neglectus* induced losses, and breeders regard *P. neglectus* to be a national priority. Quantitatively inherited partial resistance and tolerance have been identified in bread wheat; however, there is a need for further research to identify more effective and useful sources of resistance and tolerance. Given that rye and triticale are relatively resistant, screening of wild relatives for resistance would appear to be worthwhile.

Septoria tritici blotch (STB)

Septoria tritici blotch caused by the fungus *Mycosphaerella graminicola* is potentially destructive in southern Australia, particularly in southern NSW where it can cause losses due to reductions in both yield and quality. The disease can be controlled either through the use of genetic resistance, or fungicides, or a combination of these.

Relatively effective laboratory and field screening procedures have been developed for the disease, so that all the practical elements are in place to allow breeding for resistance in priority areas. In southern NSW, the disease was a significant problem in the late 1960s and early 1970s owing to the widespread use of susceptible varieties. However, through the use of resistant or moderately resistant varieties, which both protect the current crop and reduce inoculum levels for the following crop, STB now rarely causes severe losses in this region.

The overseas experience of genetic variability in the pathogen, and the potential for specific genes for resistance to break down, suggests that on-going research and breeding for resistance will be required to control the disease on a continuing basis.

Staganospora (syn. Septoria) nodorum blotch (SNB)

Staganospora nodorum, which causes leaf and glume blotch in bread and durum wheats, is a significant disease across the southern wheat belt, but is of particular importance in the wetter parts of WA. Breeders regard SNB as a regional priority. The preferred method of control is by the use of resistant cultivars, however resistance to the disease is quantitative and complex. Further screening for resistance is difficult because of interactions between disease levels and developmental factors such as height and maturity as well as environmental conditions. Research is currently focussed on identifying sources of resistance and developing molecular markers to facilitate their use in breeding programs.

Stem rust

Stem rust is a potentially devastating disease particularly in NNSW and southern Queensland. While effective resistance sources are available for breeders, continuing research is required to ensure that resistance is maintained against new pathotypes. As with stripe rust, breeders are interested in utilizing sources of adult plant resistance. The disease has been effectively controlled for several decades in the areas at greatest

risk using resistant cultivars. Research is coordinated through the National Cereal Rust Control Program.

Stripe rust

Since its introduction into Australia, stripe rust has proved to be a recurrent and significant problem in southern Australia. It has also proved to be evolutionarily labile and demonstrated it can quickly overcome many single major genes. There is also the ever present threat of incursion of new pathotypes. Genetic solutions include adult plant resistance, and breeders have emphasised the need for effective high throughput screening. Research on the disease is coordinated through the National Cereal Rust Control Program.

Abiotic

Drought tolerance/ water use efficiency

This is recognised as a critical and challenging area. The Pre-breeding Alliance held a two-day workshop on this topic in September 2007, with the aim of developing a national strategy for improving the effectiveness of the national pre-breeding effort on the performance of water-limited crops. The workshop report is available on the Alliance website: www.grdc.com.au/prebreedingalliance

Breeders have made it clear that they are not interested in specifically targeting severe droughts, but are prepared to use traits that have been proven to be useful in a given target area and that have no serious negative effects on their main selection targets, such as maturity, height, disease resistance, and grain quality. For routine selection of a given trait in a breeding program, they need selection tools for that trait that are cheap, simple, fast, and reliable.

Several promising physiological and morphological traits are at an advanced stage of pre-breeding or have already been incorporated into cultivars. These include: coleoptile length, vegetative vigour, carbon isotope discrimination, depression of canopy temperature, copious water-soluble carbohydrates, and duration of green leaf area during grain-filling. It is recognised that different traits may be important at different stages of crop development. For example, long coleoptile and large grain size may be effective in improving establishment of the crop, whereas copious water-soluble carbohydrates stored in the stems may contribute to grain filling.

It is notable that almost all of the traits discussed at the workshop were concerned with improving the development of the crop or its carbon economy, rather than with plant water stress per se. This observation reinforces the view that terms like “drought tolerance” have proven to be confusing and without consistent meaning in the context of pre-breeding.

Frost tolerance

Spring radiation frost can cause significant losses in yield and quality throughout much of the Australian wheat growing areas. However, the indirect losses from frost, from the need to delay sowing to be sure of avoiding catastrophic losses to frost, resulting in grain filling under hotter and drier conditions, is probably several times greater than the loss to frost itself

Research on variation in wheat for frost tolerance at heading and flowering has had a long and largely unproductive history both in Australia and in a number of overseas countries especially in Latin America. However, recent research in barley at the University of Adelaide has identified a significant degree of frost tolerance in the Japanese barleys Haruna Nijo and Amagi Nijo. The chromosomal location of the major gene underlying these tolerances has been reported and molecular markers have been developed to facilitate their incorporation into commercial cultivars.

The Pre-breeding Alliance has proposed to hold a workshop on frost in early 2008, to develop a research strategy that builds on existing research and to determine the merits of further research to identify genetic frost tolerance in wheat.

Salinity tolerance

Screening of diverse germplasm collections has revealed wide variation in tolerance to salinity in bread and durum wheat and their wild relatives. Breeders regard salt tolerance to be of national importance, with dryland salinity an increasing and intractable problem in much of the Australian wheat belt. Salinity tolerance genes are being incorporated into advanced lines in both durum and bread wheats. Efforts are also underway globally to transfer the salt tolerance from annual and perennial wild relatives to wheat.

As with ‘drought’ tolerance, a distinction needs to be made between survival and productivity. While halophytes survive in salt marshes their growth is often very poor, and it is not survival but increased production that will be of benefit to wheat growers. Salt tolerances identified in the laboratory and glasshouse still need to be demonstrated under field conditions, to determine what benefits they can offer growers.

Quality

The Pre-breeding Alliance held a two-day workshop on wheat quality in November 2007. The workshop brought together experts from different areas of research and industry, with the aim of improving the effectiveness of the national pre-breeding effort for enhanced wheat quality.

An agreed action from the workshop was to develop a series of position papers to summarise current understanding of important areas and make specific recommendations for the support of future research in these areas. The final report could be completed by the end 2008.

The following quality traits are regarded as priority national targets for pre-breeders but are still awaiting final endorsement by industry stakeholders and the Steering Committee of the Pre-Breeding Alliance

Defect Elimination

Late Maturity Alpha-amylase (LMA)

Late maturity alpha-amylase is a genetic defect that can result in the accumulation of damaging levels of alpha-amylase in wheat grain in the absence of weather damage or sprouting. In cultivars susceptible to LMA low temperatures trigger enzyme production during a critical period of grain filling about 25-35 days after flowering. Varieties carrying this defect are common in CIMMYT germplasm, particularly lines derived from synthetic wheats.

Research on LMA has increased recently as efforts have been initiated to eliminate LMA from the Australian milling wheat industry. Breeders regard LMA as a priority national target.

The trait is under genetic control, however is a complex interaction with environment leading to variability in expression. Research is hampered by difficulties in obtaining a reproducible phenotype in some lines. While there are encouraging preliminary results in identifying molecular markers for a tendency to produce LMA, further research is required to validate these in different genetic populations.

Pre-harvest sprouting

Pre-harvest sprouting is a major recurrent problem in the northern wheat areas of Australia but is also a sporadic but occasionally very damaging problem in other areas. Sprouted grain is often downgraded to feed because of low falling number or other problems. Pre-harvest sprouting is generally a greater problem in white than red wheats, where it has been easier to breed for high levels of dormancy that provide several weeks of post ripening protection against summer rains.

Pre-harvest sprouting has been a major priority for research in Australia for more than 25 years. This research has established significant variation in tolerance to pre-harvest sprouting in bread and durum wheats due to dormancy. It has also established

additional variation in wild diploid wheats that has been transferred to bread wheats. Combination of the best sources of resistance should provide in white wheats a level of tolerance close to that in the most tolerant red wheats.

This research has also established that tolerance to pre-harvest sprouting is controlled by a gene expressed in the embryo, which can interact with one or more other genes expressed in the seed coat. Molecular markers have been developed for the embryo dormancy gene and are in the process of being developed for the embryo coat genes.

Sprouting remains a major industry priority. Further research is required to examine how to best combine additional tolerance factors identified in the wild relatives of wheat with those intensively studied in bread wheat in adapted backgrounds.

Dough Mixing Characteristics (Strength, extensibility, mixing time)

Flour water absorption for bread manufacture

Milling yield

Quality for Asian markets

- ***Noodle manufacture***
- ***Bread making quality***