Development and evaluation of weed competitive wheat varieties

Summary
The project identified weed competitive wheat lines that can consistently provide up to 50% reduction in weed seed-set compared with commercial varieties. Field studies at multiple sites showed that there was considerable consistency in weed suppression of wheat lines across different environments. Field studies also confirmed that wheat lines with superior competitive ability against oats were also effective against ryegrass and mustard. Finally, there was strong evidence to show that weed competitive wheat lines can be integrated with higher seed rate and pre-emergence herbicides to become an effective component of integrated weed management on Australian farms.

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Conclusions
Rapid increase in the level of herbicide-resistant weeds is making it difficult for Australian farmers to achieve effective weed control on their farms. Wheat is considered to be a poor competitor against weeds compared with other cereal crops, which allows surviving weeds to set large amounts of seeds. An improvement in the competitive ability of wheat could play a vital role in an IWM program to manage herbicide resistance. Further evaluation of the high vigour breeding population developed in a previous project (UA00061) showed significant gains in competitive ability. The most competitive wheat lines were capable of reducing ryegrass seed set by more than 50% compared with current commercial varieties. The combination of pre-emergent herbicides with competitive wheat lines provided significant additional benefits over their use with commercial varieties. Weeds that survived pre-emergence herbicides were able to set large amounts of seed in commercial varieties but the high vigour lines were able to reduce seed set in the surviving weed by greater than 50% in comparison to commercial varieties.

These highly vigorous wheat lines provide rapid early ground cover, which is an advantage when competing with weeds. High early vigour associated with large embryo size and alternative dwarfing genes in this wheat population (Rht8, Rht12 and Rht13), has provided these lines a competitive advantage that is not reliant on plant height. After extensive field experiments the expression of increased competitive ability was found to be stable across environments of contrasting rainfall and different weed species. These findings suggest a more competitive wheat variety would provide benefits for weed management in a range of environments and weed species. This also has provided a valuable insight for the adoption of this germplasm by Australian wheat breeding programs. Associated with the large gains in competitive ability there are some short-comings in the current selection of high vigour lines. This includes a slight yield penalty associated with increased vigour, poor levels of disease resistance and inadequate grain quality standards. However, these traits can be enhanced through crossing by the local wheat breeders. This project has successfully evaluated these high vigour lines and shown the significant benefits high vigour wheat lines can provide in weed management, especially when used as part of an IWM package.

Recommendations
During the three years of this project, it has become clear that high vigour wheats can make a significant contribution to the management of herbicide-resistant weeds on Australian farms. Up to 50% reduction in weed seed-set in comparison to currently grown wheat varieties has been consistently observed. As part of an IWM program, adoption of weed-competitive wheat lines would significantly assist in managing herbicide-resistant weed populations. The next stage in the progression of these high vigour wheat lines is to make them available to wheat breeders for them to incorporate into germplasm. During the course of this project, a substantial dataset has been accumulated, which includes detailed information of above and below ground plant traits associated with competitiveness, grain yield, disease and grain quality information. This provides breeders with an informative background of the breeding lines for future work. Breeders from Longreach have already shown strong interest in the material and have been given access to selected lines for via material transfer agreement.
Outcomes

Due to the long-term nature of pre-breeding research, there has been no direct benefit to Australian agriculture so far from this project. However, direct engagement with wheat breeders has resulted in delivery to them of selected germplasm. A Material Transfer Agreement was signed with Longreach Plant Breeders and selected wheat lines were then delivered to them for use in their breeding programs.

Economic benefits: Evidence from research undertaken shows that integration of weed competitive lines with high seed rate and pre-emergence herbicides will deliver large benefits to growers in terms of weed suppression and reduced crop yield loss. However, these benefits will only become a reality in future when varieties based on these high vigour lines become available to Australian growers.

Environmental benefits: Wheat with increased competitive ability, especially when integrated with other IWM techniques, such as high seeding rate or windrow burning, would reduce reliance on herbicides and reduce the input of these chemicals into the environment.

Achievements/Benefits

Weed management is widely regarded as critical for achieving productivity and profitability in Australian farming systems. As a consequence of the widespread development of herbicide resistance in many weed species, the importance of weed management in Australian agriculture has become even greater. Among cereal crops, wheat is widely regarded as the weak link for weed management. Weaker weed competitiveness of commercial wheat varieties allows weeds that escape herbicide application to set large amounts of seed and replenish the seed bank for subsequent crops. Development of wheat varieties with improved weed competitive ability would assist in reducing weed seed-set. During a previous GRDC project (UA00061), a novel wheat population was developed in which lines were selected primarily for high early vigour and ability to compete with weeds. This wheat population contained alternative dwarfing genes (Rht8, Rht12 and Rht13) that were gibberellic-acid sensitive. This research enabled development of mid-short height wheat lines that possessed high early vigour. Previously combining high early vigour with short stature was difficult because of the negative effects of the commonly used dwarfing genes (Rht1 and Rht2) on early vigour. The current project (UA00112) followed on from the outcomes of the previous project to further evaluate the ability of these wheat lines to consistently compete with weeds across different environments and weed species.

A selection of approximately 100 of the most vigorous and agronomically suitable experimental wheat lines were grown in three contrasting environments of differing rainfall in South Australia. Locations were Mintaro (high rainfall), Roseworthy (medium rainfall) and Palmer (low rainfall). These field experiments used oat (Wintaroo) as a weed surrogate to establish consistent densities to best identify genotypic differences in competitive ability. Each wheat line was grown in pure and mixed stands with oat to assess weed tolerance and suppression. In these experiments, the gains in competitive ability of the high vigour lines were clear. The most suppressive wheat lines reduced oat seed production by almost 50% compared with current commercial varieties. Even though these high vigour experimental lines were not selected for grain yield, some of the lines produced grain yields similar to current commercial varieties. When grown in competition with oat, the best yielding, high vigour lines produced significantly greater yields than most commercial varieties.

Data gathered during the two seasons of field investigations showed that the competitive ability of wheat was relatively stable across the environments and seasons. The best performing lines at Roseworthy were highly ranked at Mintaro and Palmer. The oat suppression component of competitive ability was consistent with seven out of 10 site by year combinations having significant correlations, ranging from r-values of 0.202 to 0.507. The only non-significant interactions occurred in 2009 season, where a sharp finish to the season was not conducive to oat seed production at the Palmer site, which was severely affected by drought.

To support the genotype x environment study, 26 of the overall best performing, high vigour lines during 2009-10 were selected and grown along with 24 commercial varieties. This experiment aimed to highlight the gains in competitive ability in this breeding population of wheat. Oat was again used as a weed mimic in these experiments. These high vigour lines again performed well, averaging 59 oat panicles/m² as compared to 97 oat panicles/m² across the commercial varieties (40% reduction).

As most field experiments were conducted using oat as a weed surrogate, it was important to validate the stability of
competitive ability across a range of weed species. Field experiments were conducted during 2009-11 using oat, ryegrass and mustard in competition with a small sub-set of wheat lines. Each weed species caused varying levels of crop yield losses but despite this, wheat lines had similar ranking for competitive ability against different weed species. This conclusion is supported by significant positive correlations between yield losses caused by each of the three weeds, with r values ranging between 0.58 and 0.77. This relationship indicates that despite changing the weed species, a wheat line showing high tolerance to ryegrass will also have high tolerance to oats and mustard. The other component of competitive ability, weed suppression, provided a much more consistent pattern of performance of wheat lines across the three weed species. Weed seed production varied between weeds due to inherent differences between them in potential seed set. On average ryegrass produced 16,000 seeds/m², as compared to 1,900 seeds/m² and 1,200 seeds/m² for mustard and oats, respectively. Rankings of wheat lines based on weed suppression was much more consistent between weeds than weed tolerance, which is supported by highly significant correlations of seed production between each of the weeds (r values: ARG/MUS=0.90, ARG/OAT=0.88, OAT/MUS=0.86). These results demonstrate that competitive ability of a specific wheat line is consistent across weed species, whether it is a grass or broadleaf species. This is important for the adoption of weed competitive wheat lines because it would be impractical to breed wheat lines for different weed species. Furthermore, weeds often occur in species mixtures, therefore weed-competitive wheat lines would need to be able to suppress all weed species present.

As ryegrass is the most problematic weed in southern Australia, it was important to show the benefits of these high vigour lines in a field infested with herbicide-resistant ryegrass. A field site heavily infested with ryegrass (approx. 1,000 plants/m²) was selected at Roseworthy in the final year of the project. Three high vigour lines were grown and compared to three commercial varieties representing each of the major wheat breeding programs in southern Australia. Incorporated into the trial were other weed management practices that are likely to be used by growers in combination with the use of competitive varieties. This included a pre-emergent herbicide treatment (nil, trifluralin® and Boxer® Gold®) and increased crop seeding rate treatment (200 and 400 plants/m²). The high vigour lines performed extremely well in their ability to suppress ryegrass seed set. The most suppressive experimental line reduced ryegrass seed set by 50-60% as compared to the commercial varieties in the absence of herbicides. This level of reduction of weed seed set was almost equivalent to the use of the herbicide, Boxer® Gold in the commercial varieties. This ryegrass population was resistant to trifluralin, which explains the low level of weed control achieved in this treatment. Boxer® Gold provided 80% control but surviving plants were still able to set large amounts of seed in the commercial varieties. This level of control combined with a competitive variety provided up to a 70% greater reduction in weed seed-set compared to commercial varieties. This result highlights the potential significant benefits from the use of a competitive wheat variety in managing troublesome weeds such as ryegrass with resistance to multiple herbicides. These high vigour lines were also highly responsive to increased seeding rates. Doubling the seeding rate provided significant increases in weed suppression in all high vigour lines. Of the commercial varieties tested, only Scout® significantly benefited from increased seeding rates but still allowed significantly more ryegrass seed-set than the high vigour lines.

Several aspects related to crop resource use of these high vigour lines were also studied during the duration of this project. This included above and below ground plant traits as well as water-use and nitrogen uptake. Crop water use was recorded throughout the growing seasons of 2010 and 2011 at Roseworthy. Large plots were used (30 x 4m) and soil water was determined using soil core samples. In 2010, there were no significant differences between the high vigour lines and commercial varieties used. However in 2011, the most vigorous wheat lines used significantly more water during early development, which did have some influence on the availability of water during grain-fill in this particular season. The high vigour lines have significantly larger leaves than conventional varieties. In the most vigorous lines, leaves 1 to 3 provide about double the leaf area than in commercial varieties. The flag leaves of high vigour lines are also substantially larger and provide up to 40% more leaf area. Consequently, high vigour lines tend to have greater early water-use and accumulation of nitrogen. Data from 2010 and 2011 showed that there can be as much as 30 kilograms per hectare more nitrogen in plant tissue samples of the most vigorous wheat lines compared with commercial varieties. Grain protein levels were equal to or greater than commercial varieties, which may be attributed to slightly lower yield potential of these lines. It is thought that these high vigour lines have larger root systems to support the increased biomass and nutrient use. This was investigated during this project through soil cores in the field and plants grown in solution culture. Root density of the high vigour lines was similar to the commercial varieties in the top 30cm of the soil profile. But further down the profile, root density of the high vigour lines was greater than the commercial varieties. Providing water and nutrients are not limiting during grain-fill, this increased N uptake early in the season could be important in obtaining a competitive advantage over weeds.

By the end of the project, 26 lines that possessed the greatest levels of competitive ability along with suitable agronomic
characteristics were identified. This enabled a closer investigation of the levels of disease resistance and grain quality. All 26 lines were used in a molecular marker assay to identify the presence of either Rht-B1b (rht1) or Rht-D1b (rht2). Of those lines, 60% did not have either gene, indicating an alternative dwarfing gene is likely to be present (rht8, rht12 or rht13). Rust resistance screening conducted by ACT, indicated most lines were highly susceptible to at least one form of rust.

Based on grain quality tests performed by Grain Growers Ltd, seven wheat lines submitted for quality testing could be used as parents for bread wheats. Range of quality tests performed included RVA viscosity, peak time, extensograph and farinograph. This provided plant breeders with broad information relating to the high vigour wheat population for future breeding work.

During the course of the project, wheat breeders from ACT and Longreach Plant Breeders have shown considerable interest in these breeding lines. Selected wheat lines were also trialled independently in Western Australia (Peter Newman) in weed competition studies, which provided promising results. Our lines have also been used locally at the MidNorth High Rainfall Zone trial site, where the greater early biomass of high vigour lines has raised particular interest from a ‘grain and graze’ perspective.

**Additional information**