Evaluation of perennial wheat germplasm in an Australian environment

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Abstract

There is interest in developing cereal plants with a perennial habit because of potential advantages in production stability and environmental sustainability. Breeding programs in the northern hemisphere have produced perennial wheats by crossing annual bread wheat lines (*Triticum aestivum*) with perennial wheatgrasses (*Thinopyrum spp*.). This study evaluated the performance of 67 of these hybrid derivatives in Australia compared to the annual winter wheat cv. EGA Wedgetail. The experiment was conducted at Cowra in the mixed cropping zone of NSW. All hybrid derivatives were significantly later in their maturity than cv. EGA Wedgetail (mean 123 days after sowing to flowering)($P > 0.05$), with 18 of the imported lines yielding as well or better than the control (mean 136.7 g/m row). Most lines containing *Th. intermedium* or *Th. ponticum* in their pedigree were highly resistant to wheat streak mosaic virus and most proved very resistant to stripe and leaf rust. Good resistance to current Australian races of stem rust was rare within the germplasm. Nine entries regrew and produced grain in the second season. These lines tended to be lower yielding in the first year. Although potential exists, ongoing research is required to strengthen perenniality, ensuring survival through the harsh Australian summers and guaranteeing adequate grain yields. Significantly, this germplasm is proving a rich resource of disease resistance.

Key Words

Perennial grains, wheat relatives, soil degradation, hybridisation

Introduction

Although a new concept in Australian agriculture, the development of perennial grains has been the goal of overseas researchers since the 1930's, with varying levels of success (Wagoner 1990). Modern agriculture based on annual cropping systems is a contributing factor to losses of genetic diversity, species loss, increases in land degradation and environmental pollution from off target movement of chemicals. The Australian Agriculture Assessment (2001) has estimated that national soil loss from cereal production is approximately 39 million t/yr on average. Although practices such as direct drilling, controlled traffic and stubble retention have had considerable effects in reducing soil erosion, only 22% of producers adopt these techniques (ABARE 2003). However, these practices do little to reduce deep drainage and the leaching of nutrients which contribute to soil acidification and dryland salinity. Perennial crops potentially have significant benefits for soil health in terms of reduced erosion, more efficient use of resources, including nutrients, water and labour, and higher sequestration of soil carbon (Bell et al. 2008).

Moderate progress in the development of perennial wheat has occurred in recent times in the USA(Cox *et al.* 2010). Researchers at The Land Institute (TLI), Kansas and Washington State University (WSU) have increased the genetic base by hybridising annual bread wheats, durum wheats and triticale with perennial relatives such as *Thinopyrum* spp. and *Lophopyrum elongatum.* By increasing the diversity within the germplasm, the likelihood of identifying lines that can perenniate in different environments is increased. In developing a cohort for evaluation in Australia, USA germplasm was supplemented with lines from Russia and China. Until now this material has been largely untested outside their countries of origin. The current study examined phenology, yield, perenniality and disease resistance under Australian conditions.

Methods

Sixty six lines of wheat-perennial wheatgrass hybrids were sown in two experiments 3 weeks apart, due to a staggered release of germplasm from quarantine. Table 1 gives a summary of the pedigrees. Both experiments contained 3 replicates arranged in a randomized design accounting for spatial distribution in rows and columns. Each plot consisted of 30 seeds of each line sown in a 1.5 m row. Experiment 1 was sown on the 3 June 2008 and contained 9 lines sourced from China and Russia, as well as 3 control treatments; annual winter wheat cv. EGA Wedgetail, intermediate wheatgrass (*Th. intermedium*) and mountain rye cv. Family 10 (*Secale montanum* syn, *S. stricnum*). Experiment 2 was sown on the 18 June and contained 56 entries from WSU and TLI, with cv. EGA Wedgetail as the control. All plots were monitored for flowering dates and hand harvested at maturity to determine grain yield. Irrigation was applied to all treatments in both experiments over the summer of 2008/09 to maintain a soil profile of moisture sufficient to allow plant regrowth. Plots where monitored for post harvest regrowth over the summer and following autumn. The responses to wheat streak mosaic virus was assayed at CSIRO, Canberra and samples sent to the University of Sydney, Cobbitty, for rust bioassays

Results

Although sown late for crops in the district, all entries established well and grew through to maturity (127 and 120 DAS for EGA Wedgetail in expt 1 and 2 respectively). In Fig 1 lines are ordered from highest to lowest yield. EGA Wedgetail had the highest yield in experiment one. Statistically there was no difference in the yield of EGA Wedgetail and that of Zhong 2 and Zhong 5. In experiment two entry 235b had the highest yield of 173.2g/m row. There were no significant differences in yields between the first 18 lines (including EGA Wedgetail, Fig 1b). WSU lines (entries 235 to 255) comprising crosses to *L. elongatum* tended to be higher yielding than those coming from TLI (entries 257 to 292) comprising crosses to *Th. intermedium*. All imported lines were later in their flowering times than the winter wheat EGA Wedgetail.

Over the summer and autumn of 2008/09 all plots where monitored for regrowth after harvest. All plots were rated out of 10 for the number of plants regrowing, with 10 being the highest regrowth score (Figure 2). The regrowth scores in experiment one were dominated by the two perennial grasses, *Th. intermedium* and mountain rye. The only other varieties to survive into year two were OK7211542 and Otrastajuscaja 38. In experiment two, seven varieties out of 57 showed an ability to regrow after harvest. Entries 236a and 257b showed significant regrowth through summer compared to the other surviving lines.

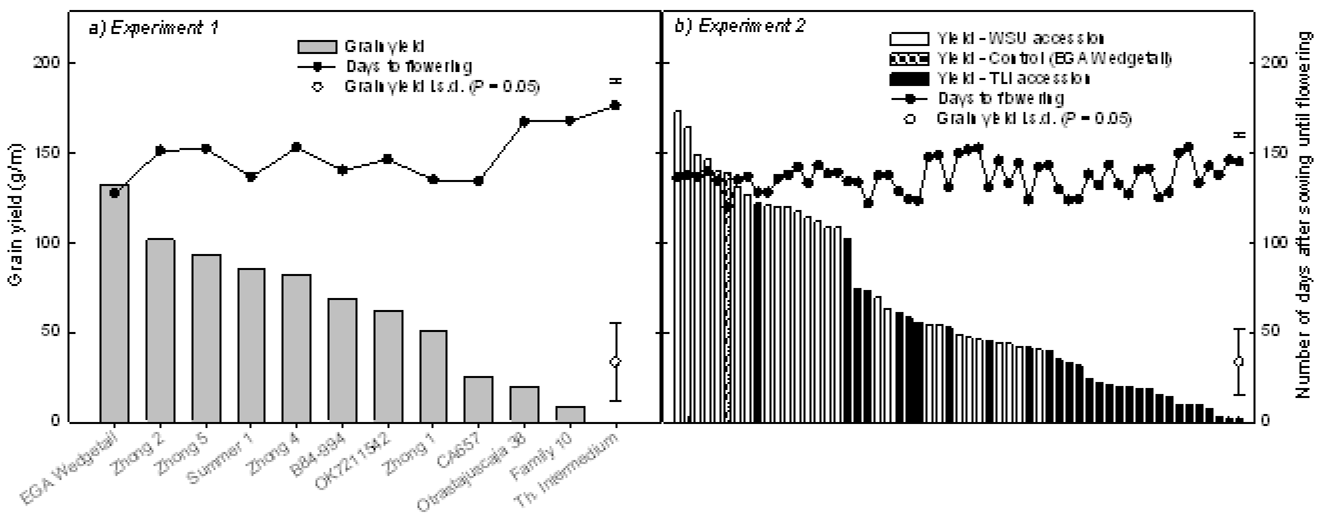

Figure 1. Yield (grams) and days to flowering after sowing (DAS) for Experiments 1 (a) and 2 (b) in the first year.

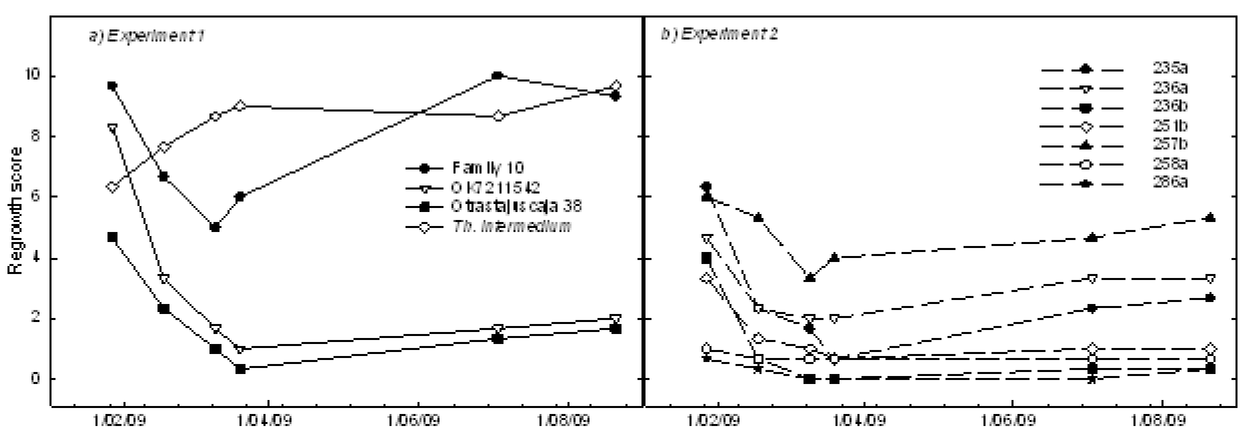

Figure 2. Scores of regrowth in the second year for Experiments 1 (a) and 2 (b)

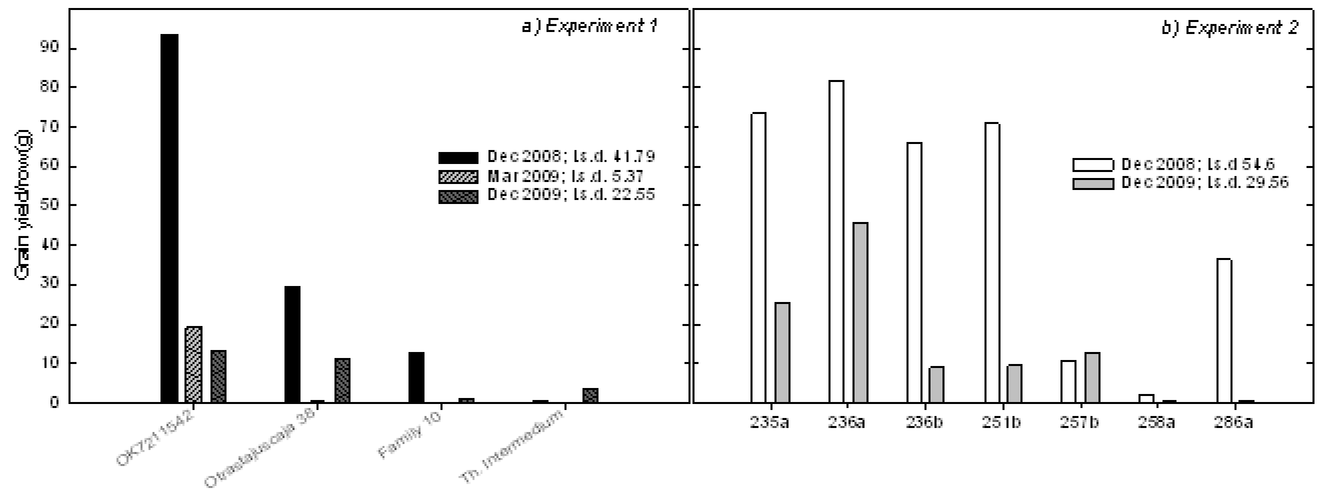

Figure 3. Comparison of second year yields of varieties in Experiments 1 (a) and 2 (b)

In Experiment 1, OK7211452 and Otrastajuscaja 38, produced three grain harvests over two years with grain harvested in both autumn and summer of year two (Fig 3). These second year harvests when added together were approximately one third of the yield in of year one. In Experiment 2, no grain was harvested in the autumn of the second year and in both trials the second year harvests where much lower than those of year one due to varying levels of plant mortality after the first season.

Bioassays conducted against the four major diseases, leaf rust, stripe rust, stem rust and wheat streak mosaic virus (WMSV) showed that lines containing *Th. intermedium* and *Th. ponticum* in their pedigree had high levels of resistance to WSMV (Table 1). All entries exhibited high resistance to stripe and leaf rust but stem rust resistance was uncommon, with most entries susceptible. One notable exception was OK 7211542 which showed resistance to all four diseases.

Conclusion

A desktop study by Bell *et al.* (2008), simulating farming system using the MIDAS model, concluded that a perennial wheat crop producing 800 kg/ha of forage during autumn with grain yields of at least 40% of conventional wheat, would be profitable in current mixed-farming enterprises. Although the germplasm in our study comprised a number of lines with grain yields comparable to that of an adapted winter wheat in their first year, none of the regrowing lines in the second year achieved 40% of the annual wheat control. Ongoing research is required to study the herbage production from this material and to understand the effect of grazing on subsequent regrowth and perenniality.

Perennial plants prioritise their resource allocations into forming vegetative structures which ensure survival at the expense of producing abundant seed. The negative correlation between plant longevity and reproductive allocation will always be an issue in the development of perennial grain crops. DeHaan *et al*. (2005) argue that the trade-off is not fixed and is influenced by many environmental and genetic factors and by applying plant breeding techniques to a population of perennial plants, the ability to increase yield is possible. The diverse range of characteristics within the germplasm in the current study suggests there is potential to improve current germplasm.

Perennial wheat may pose a threat to traditional annual wheat production, if it serves to harbour and increase inoculum of diseases and pests. This threat is lessened if the perennial wheat line senesces over summer so that it does not form a green bridge. Furthermore, perennial Triticeae are often good sources of disease resistance and this study has highlighted this disease resistance (Table 1). Managing diseases will require a change in agricultural practices, since common cultural techniques, such as crop rotation, used in annual production systems may no longer be suitable. Indeed, Cox *et al*. (2005) advocate new management techniques, such as the mixing of crop cultivars of varied resistance together with the periodic burning of residues to control pests and diseases, thereby reducing the risks posed by perennial crops.

Table 1. Disease ratings for 43 lines of perennial wheat compared to cv. EGA Wedgetail. Two or more scores in a cell indicates multiple reactions within a population.

Line	Pedigree	WSMV	Stripe Rust	Leaf Rust	Stem Rust
233a	Le/Ta/Ta	Susceptible	1	2	6,9
234a	Le/Ta/Ta	Susceptible	1	2	6,9
235a	Le/Ta/Ta	Susceptible	2	2	6,8
236a	Le/Ta/Ta	Susceptible	2,9	2	5
237	Le/Ta/Ta	Susceptible	3,6	2	9
239a	Le/Ta/Ta	Not tested	1,2	2,7	2,9
240b	Le/Ta/Ta	Susceptible	1	2,3	8,9
242a	Le/Ta/Ta	Susceptible	1,2,4	2,3	5,9
243a	Le/Ta/Ta	Susceptible	1	2	8,9
244a	Le/Ta/Ta	segregating	2	3	6
245a	Le/Ta/Ta	Susceptible	1	6,7	9
248a	Le/Ta/Ta	Susceptible	3,6	3,4	8
251a	Le/Ta/Ta	Susceptible	1	2	5,6
252a	Le/Ta/Ta	Susceptible	1	2	9
253a	Le/Ta/Ta	Resistant	1	6	9

254a	Le/Ta/Ta	Susceptible	1	4,6	9
255a	Le/Ta/Ta	Susceptible	1,8	2	8,9
257a	Tc/Ti//Ta	Resistant	2	*	3
258a	Tc/Ti//Ta	Resistant	2,8	6	9
259a	Tc/Ti//Ta	Resistant	2	6	9
260a	Tc/Ti//Ta	Resistant	3	6	6,7
261b	Tc/Ti//Ta	Resistant	2	4	6
262a	Tc/Ti//Ta	Resistant	3	3	9
264a	Tc/Ti//Ta	Resistant	4	2	9
266a	Tc/Ti//Ta	Susceptible	1	2	2,7
267a	Tc/Ti//Ta	Susceptible	1	2	4
268a	Tc/Ti//Ta	Resistant	1	2	4,8
269b	Tc/Ti//Ta	Susceptible	7	*	3
270a	Tc/Ti//Ta	Resistant	1	2	7,8
271a	Tc/Ti//Ta	Resistant	1	2	8,9
272a	Tc/Ti//Ta	Susceptible	1	2	7
274a	Tc/Ti//Ta	Resistant	1	2,3	7,9
286a	Tc/Ti	Resistant	1,2	2	8
292b	Tc/Ti//Ta/3/Ta	Susceptible	1,3,8	2	4,8

Otrastajuscaja 38	Ta/Tp 2n=56	Resistant	3	2	8
OK7211542	Ta/Tp 2n=56	Resistant	1	2	3
CA657	*T.durum/H. villosa*	Susceptible	1	5	2
B84-994	Ta/*A.scirpeum*//Ta	Resistant	1	5	9
Summer 1	Ta/Tp 2n=56	Resistant	1	2	2
Zhong 1	Ta/Tp 2n=56	Resistant	2	2	2,5
Zhong 2	Ta/Tp 2n=56	Resistant	3	2	3
Zhong 4	Ta/Tp 2n=56	Resistant	1	2	4
Zhong 5	Ta/Tp 2n=56	Resistant	1	2	4
EGA Wedgetail	Ta	Susceptible	3	2	2

Tc = Triticum carthlicum; Ti = Thinopyrum intermedium; Ta = Triticum aestivum; Le = Lophopyrum elongatum; Tp = Thinopyrum. ponticum;

A. scirpeum = Agropyron scirpeum; H. villosa = Haynaldia villosa

WSMV; Wheat Streak Mosaic Virus; 0 = Very resistant; 9 = Very susceptible. Multiple numbers signifies signify variable reactions within the sample.

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