

Is synthetic hexaploid wheat a useful germplasm source for increasing grain size and yield in bread wheat breeding?

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ABSTRACT

Bread wheat (*Triticum aestivum* L.) evolved from limited hybridisations between *Triticum turgidum* L. and *Aegilops tauschii* Coss., restricting genetic diversity. Human-assisted crossing between these progenitors can be used to create synthetic hexaploid wheat that readily hybridises with bread wheat cultivars, providing an additional source of genetic diversity for breeding. Synthetic hexaploids have been reported to be useful for increasing both grain size and grain yield in bread wheat breeding. The objective of this study was to investigate variation in grain size and yield potential of synthetic-derivatives under south-eastern Australian conditions. Twenty-seven synthetic hexaploids were backcrossed to Yitpi, an elite south-eastern Australian bread wheat, with the resulting progeny developed into 27 families of 15 to 48 BC₁F_{4,6} lines. Evaluated at a typically high yielding environment in south-eastern Australia in 2006, under rainfed conditions, mean thousand grain weights of all 27 families were found to be similar to or higher than that of the recurrent parent Yitpi. One family had a thousand grain weight 9.8% above that of Yitpi. Mean grain yields of the families were all lower than that of Yitpi. As 2006 was a drought year, these results indicate that synthetic hexaploids can contribute to increased grain size under a water stressed environment, but further evaluation is required to understand whether significant increases in grain yield can be achieved.

INTRODUCTION

Primary synthetic hexaploid wheats are the product of human-assisted crossing between *Triticum turgidum* L. (AABB) and *Aegilops tauschii* Coss. (DD), the evolutionary progenitors of common bread wheat (*Triticum aestivum* L.; AABBDD)^{1,2}. Both synthetic hexaploid and bread wheats have the same genetic constitution, and therefore can be readily crossed. Modern, landrace and primitive forms of *T. turgidum*, and different *Ae. tauschii* accessions can be used to create primary synthetic hexaploids, making synthetic hexaploids a unique germplasm resource for bread wheat breeding. Synthetic hexaploids can act as a vehicle for the introduction of specific characters or general genetic diversity from these progenitors into bread wheat backgrounds. As the hybridisation events that formed bread wheat are thought to be limited, the genetic diversity obtainable from synthetic hexaploid wheats may contain, for example, novel alleles and genes for

biotic and abiotic stress tolerances not currently represented within the *T. aestivum* gene pool^{3,4}.

Increased grain size in bread wheat has a favourable effect on milling yield. Large grain have higher endosperm to surface area ratios, improving milling yields with reduced by-products (bran and pollard)⁵. Increases in grain yield over the last 40 years have come partly from the use of gibberellic acid-sensitive dwarfing genes (*Rht-1* and *Rht-2*), which were globally distributed during the 'green revolution'. In addition to reducing plant height, these genes increase seed set and the number of kernels per m² compared to normal stature wheats. These changes have been accompanied by reductions in grain size^{6,7}.

Synthetic hexaploids have been proposed as sources of genetic material for the improvement of grain size (1000-grain weight) in bread wheat breeding⁸. Some synthetic hexaploids have also achieved yields similar to those of check cultivars under drought stress⁹. Backcrossing and top-crossing strategies have been employed to exploit primary synthetic hexaploids for these characters in both elite CIMMYT and local bread wheat backgrounds^{10,11,12}.

In south-eastern Australia, trials evaluating synthetic derivatives using local and CIMMYT recurrent bread wheat parents have had mixed success. Selected BC₁F_{2,6} derivatives have yielded more than the local recurrent parent in low-yielding environments, with improvements usually associated with increased grain size¹¹. Other studies have produced few synthetic derivatives that were high performing in a south-eastern Australian high yielding environment, with increased yields of up to 110% of that of the best local check cultivar¹³.

The objective of this study was to investigate variation in grain size and yield of a previously unassessed set of synthetic-derived backcross lines in a typically high-yielding environment in south-eastern Australia. Identification of high-yielding families with large grain size could be useful in identifying synthetic hexaploids suitable as new sources of genetic diversity for wheat breeding in south-eastern Australian environments.

MATERIALS AND METHODS

Germplasm and field trials

Twenty-seven primary synthetic hexaploids were used in this investigation. Their Australian Winter Cereals Collection accession numbers are as follows: AUS 29636, AUS 29637, AUS 29638, AUS 29640, AUS 29642, AUS 29644, AUS 29645, AUS 29646, AUS 29653, AUS 29654, AUS 29655, AUS 29656, AUS 29657, AUS 29659, AUS 29660, AUS 29664, AUS 29666, AUS 29668, AUS 29670, AUS 29676, AUS 29677, AUS 29678, AUS 29680, AUS 29681, AUS 29682, AUS 29684 and AUS 29685. Each primary synthetic hexaploid was backcrossed to Yitpi, a bread wheat cultivar that is adapted to south-eastern Australia. Selections were made from BC₁F₄ bulk plots in 2005 (Roseworthy, South Australia), with between 15 and 48 lines selected from each of the 27 bulk plots. Selections were based on similar height and growth habit to that of Yitpi. Twenty-seven families of BC₁F_{4.6} lines were evaluated in 2006, together with five south-eastern Australian bread wheat check cultivars in a partially replicated (20%) field experiment at Roseworthy, under rainfed conditions. Each plot consisted of six rows (1.2m x 3.25m; 3.9m²).

Grain measurements

Thousand grain weight measurements were recorded from each plot, whereby a random 500 grains were counted with the subsequent weight (g) multiplied by two. Grain yield (kg/ha) was recorded as the weight of grain harvested from each plot (g), divided by 0.39.

Environmental effects

Crown rot symptoms (causal agent *Fusarium* spp.) were observed and were assessed on a scale of 1 to 9, where 1 represented no visible symptoms, and 9, nearly 100% of heads within plots with minimal chlorophyll colouration.

Data analysis

'R' statistical software with the ASReml package was used for the analysis¹⁴. A linear mixed model was fitted accounting for both genetic and environmental effects, with crown rot treated as a covariate. Best linear unbiased predictions (BLUPs) were generated for thousand grain weight and grain yield values for individual genotypes, families of lines, and all lines across families treated together in a 'Synthetic Group'.

RESULTS

Thousand grain weight

Mean thousand grain weights of all 27 families were similar to or higher than that of the recurrent parent Yitpi, with 7 families significantly ($P>0.05$) higher, as seen in Figure 1. Primary synthetic hexaploid parents AUS 29637, AUS 29668, AUS 29659, AUS 29638, AUS 29640, AUS 29653 and AUS 29681 were in the

pedigree of these families. The highest mean thousand grain weight of a synthetic-derived family was 9.8% above the recurrent parent, with its respective lines having values ranging from 20.6g to 34.2g (Yitpi, 26.1g). Across all families, 20% of all lines had thousand grain weights significantly ($P>0.05$) higher than the elite recurrent parent. When all lines from all families are analysed together in a 'Synthetic Group' (Figure 1), its mean was significantly above that of Yitpi.

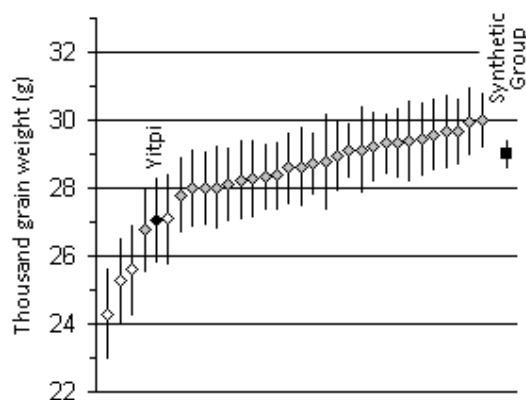


Figure 1. Mean thousand grain weights (g) of 27 synthetic-derived families of lines \blacklozenge recurrent parent Yitpi \blacklozenge , local elite check cultivars \blacklozenge , and all lines within all families treated as a synthetic group \blacksquare . Error bars represent $\pm 2x$ standard error of mean.

Yield

Mean grain yields of synthetic-derived families were all significantly ($P>0.05$) below that of Yitpi, ranging from 70% to 82% of the recurrent parents' grain yield, as seen in Figure 2. None of the individual lines yielded more significantly than Yitpi, 5% of all lines produced grains yields not significantly different to Yitpi.

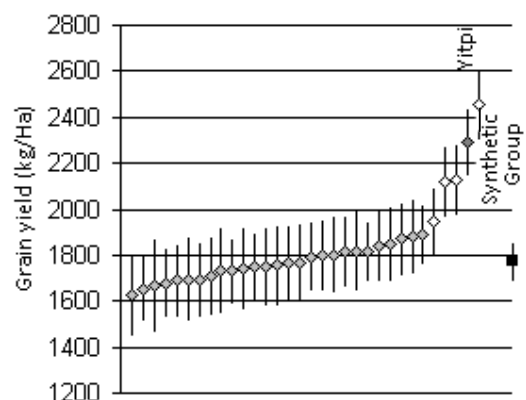


Figure 2. Grain yield (kg/Ha) of 27 synthetic-derived families of lines \blacklozenge recurrent parent Yitpi \blacklozenge , local elite check cultivars \blacklozenge , and all lines within all families treated as a synthetic group \blacksquare . Error bars represent $\pm 2x$ standard error of mean.

DISCUSSION

The thousand grain weights recorded for BC₁F_{4,6} synthetic-derived families of lines showed that superior grain size can be achieved using this germplasm resource. All synthetic-derived families had similar or higher mean thousand grain weights than the local recurrent parent Yitpi. However, under the severe drought conditions experienced in this trial, none of the synthetic derived lines out yielded the recurrent parent, indicating that the observed increases in grain size may have been compensated for by decreases in grain number.

Full assessment of the potential of these materials will require evaluation in additional environments. Furthermore the exploitation of these materials to improve the grain size and/or grain yield of bread wheat is likely to require additional crossing with elite breeding materials.

CONCLUSION

These results indicate that synthetic hexaploids can contribute to increased grain size, but further research and breeding effort is required to understand whether these increases can provide useful contributions to grain yield.

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