# Genetic opportunities in exploiting genotype × row spacing for rainfed wheat

Greg Rebetzke[1], Kathryn Bechaz[2], David Smith[3], Tina Rathjen[1], Neil Fettell[4], Andrew Fletcher[5], Cathrine Ingvordsen[1]

[1] CSIRO Agriculture and Food, Black Mountain Science and Innovation Park, Canberra, ACT, 2601, greg.rebetzke@csiro.au
[2] NSWDPI, Yanco Agricultural Institute, Yanco NSW 2703
[3] CSIRO Agriculture and Food, Yanco Agricultural Institute, Yanco, NSW 2703
[4] Central West Farming Systems, 1 Fifield Rd Condobolin, NSW 2877
[5] CSIRO Agriculture and Food, Centre for Environment and Life Sciences, PMB 5, Wembley, WA 6913

## Abstract

Optimising row spacing is a key target to better manage limited soil water, weeds and optimise radiation interception to increase biomass and yield in rainfed systems. Studies to date indicate little opportunity with current wheat varieties to exploit genetic improvement when targeting variable wheat populations and genotype × row spacing interaction. The exploiting of novel genetics offers potential to develop synergies with specific farming systems not routinely selected for in commercial breeding programs. Early vigour genes bred into wheat through novel recurrent selection methods show promise of more rapid leaf area development, a trait by which crop water-use and water productivity may be improved in wide row situations. Narrower row spacings were associated with significantly greater light interception, grain yield (3.6 vs 2.9 t/ha) and total biomass (10 vs 7.7 t/ha). Commercial bread and durum wheats, and triticales intercepted significantly less radiation than high vigour-selected wheats under wide row spacing. Comparisons between low- and high vigour selected lines indicated a small increase in yield with greater vigour in wider rows. Identification of high-yielding lines with greater early vigour indicate potential to select wheats with adaptation to wider row spacing.

## Key Words
Breeding, pre-breeding, genotype × management interactions, water productivity

## Introduction

Adoption of no-till and stubble retention farming systems has seen increased interest in wider row spacings for winter cereals including wheat. Capacity to increase row spacing is seen as a simple tool for growers to better manage stubble loads, increase sowing speeds, and capacity for inter-sow rows. However, wider rows have been associated with greater weed incidence owing to reduced crop competition (Borger et al., 2017). Reducing row spacing is associated with increasing grain yields for wheat in rainfed systems in WA (Borger et al., 2017) and southern NSW (Scott et al., 2013), and these increases are consistent with reports on increasing grain yields with reductions in row spacing elsewhere (e.g. the United States; Roth et al., 1984; Johnson et al., 1988). The influence of row spacing on soil water use and water productivity is less well-understood with growers using wider row spacings as a water conservative strategy in low-yielding regions of the wheatbelt (less than 3 t/ha) to reduce leaf area/biomass per unit sown area. In productive regions with higher in-crop rainfall, wider spacings may limit yield potential due to greater water evaporation and reduced leaf area.

Row spacing studies are typically undertaken using commercially available wheat varieties bred for average performance across a range of potential farming systems and environments (Cooper et al., 2001; Rebetzke et al., 2014; Scott et al., 2013). In turn, genotype × row spacing interaction effects are small to non-existent suggesting little benefit in targeting selection of spacing-adapted wheats in breeding for wider rows. The potential exists to focus selection on alleles for improved performance from genetic resources less used in commercial breeding programs. For example, repeatable genetic variation under strong additive genetic control exists for seedling or early leaf size (Rebetzke and Richards 1999). More vigorous wheats producing greater leaf area early in the season may have potential to better exploit increasing row spacing and greater efficiency in soil water management. A long-term S1 recurrent selection breeding program initiated from intercrossing across 30 globally-diverse high early vigour wheat genotypes has delivered wheat germplasm producing greater early leaf area (Zhang et al., 2015). The development of these genotypes was based solely on selection for wider leaves in seedlings sown after standardising to a common seed weight (Rebetzke and Richards, 1999). Cycle 3 derivatives have been top-crossed with Australian commercial wheats to improve agronomic quality whilst retaining greater early vigour. This paper reports on experiments aimed at assessing the performance of high- and low-selected vigour sister lines grown at a common sowing density at two row spacings.

## Methods

A diverse set of cereal entries including 28 wheat varieties with breeding lines selected for high and low vigour (recurrent selection derived), and triticale varieties were sown under irrigated and rainfed conditions at the Yanco Managed Environment Facility in 2017. Target plant density was 140 plants/m$^2$ sown at either 25 cm row spacing, and between rows using GPS at 12.5 cm row spacing. Measurements were made of early leaf area and biomass, ground cover and light interception, anthesis biomass and then grain yield, spike number and biomass at maturity. Soil-water was also measured in the irrigated treatment in 2017. Entry × row spacing treatments were replicated three times in a split-block experimental design with row spacing as a whole plot and entries as a split plot factor. Data were analysed using Genstat 16 (VSN 2017). For analysis, entries were grouped and contrasts developed according to source i.e., high vs low vigour selections along with commercial wheat and triticale varieties.

## Results and Discussion

Average plant number was the same (131 and 130 plants/m$^2$ and 128 and 132 plants/m$^2$) for narrow and wide row spacings, in irrigated and rainfed treatments, respectively. Light interception was significantly greater throughout vegetative growth with narrower row spacing (Table 1), reflecting the greater leaf area indices and better spatial arrangement of plants soon after emergence (data not shown). Despite the greater light interception, anthesis biomass and numbers of fertile tillers did not differ between wide and narrow rows. However, at maturity, grain yield was significantly greater with reduced row spacing and this result reflected increases in numbers of fertile spikes and final (maturity) biomass. The greater yields were associated with increased numbers of grains per unit area (i.e. m$^{-2}$) in narrow rows while seed size and harvest index were unchanged (Table 1).

Genotypic differences were large and statistically significant across row spacings for most measured attributes (Table 2). The relatively smaller grain yields in the low and high vigour selected wheats reflected that these lines were only 50% commercial genetic background, and that their development and selection was focussed on early vigour and agronomic quality (i.e. common heights and anthesis date) and not grain yield *per se*. That aside, selection for greater early vigour ('HV') was associated with greater leaf area at both row spacings, and these translated into significantly greater light interception for the high vigour-selected lines. Three high vigour selections produced an average 1.75 m$^2$/m$^2$ LAI area when averaged across both 12.5 and 25 cm row spacings (data not shown). These same high vigour selections intercepted *c.* 55% of radiation under wide rows at the first measurement time (09/08) highlighting a near-doubling of the light intercepted by the commercial wheat checks at the same spacing. Further, light interception of these wheat lines was as great, or greater, than triticale which is considered among the most vigorous of the winter cereals.

Table 1: Influence of row spacing on light interception (LI) and agronomic performance of wheats and triticales sown at 12.5 and 25 cm row spacing at the Yanco Managed Environment Facility in 2017.

| Row Spacing | LI. 09/08 (%) | LI 25/08 (%) | LI 17/09 (%) | Anthesis biomass (g/m$^2$) | No. tillers (m$^{-2}$) | Plant height (cm) | Grain yield (t./ha) | Maturity biomass (t/ha) | Harvest index | No. grain (m$^{-2}$) | Seed size (mg) | No. Spikes (m$^{-2}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.5 | 44 | 60 | 77 | 624 | 349 | 68 | 3.57 | 9.96 | 0.361 | 8860 | 41 | 408 |
| 25.0 | 36 | 51 | 66 | 601 | 331 | 68 | 2.89 | 7.70 | 0.377 | 7170 | 41 | 359 |
| Prob[A]. | 0.001 | 0.001 | 0.001 | 0.344 | 0.749 | 0.897 | 0.001 | 0.001 | 0.202 | 0.001 | 0.469 | 0.001 |

[A] probability that row spacing means are statistically different

Comparisons between the wheat groups at the two row spacings indicates strong genotype × row spacing interaction with reductions in grain yield for all including the commercial wheats at the wider row spacing (Fig. 1). Among commercial wheats, bread wheat Suntop and to a lesser extent Axe and durum wheat variety Jandaroi were all reduced in grain yield with wider row spacing whereas variety Mace was well-adapted to both narrow and wider row spacing. The broad adaptation of Mace is consistent with its established broader adaptation across a wide range of farming systems. That aside, a number of high vigour selected wheats also performed well at both narrow and wide row spacings (Fig. 1) despite their selection for early leaf area alone.

Table 2: Genotypic differences in wheats (commercial bread and durum) and triticales for light interception (LI) and agronomic performance when sown at 12.5 and 25 cm row spacing at Yanco Managed Environment Facility in 2017. 'LV' and 'HV' represent low and high vigour selections, respectively.

| Row spacing | Entries/ groups | LAI 27/08 ($m^2/m^2$) | LI. 09/08 (%) | LI 25/08 (%) | LI 17/09 (%) | Anthesis biomass (t/ha) | Grain yield (t./ha) | Maturity biomass (t/ha) | Harvest index | No. grain ($m^{-2}$) | Seed size (mg) | No. spikes ($m^{-2}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.5 | LV | 1.30 | 45 | 60 | 79 | 6.27 | 3.43 | 9.45 | 0.362 | 8440 | 41 | 407 |
| | HV | 1.58 | 48 | 60 | 78 | 6.12 | 3.57 | 9.81 | 0.366 | 8499 | 42 | 371 |
| | Comm. | 1.31 | 44 | 58 | 81 | 6.79 | 4.23 | 11.6 | 0.373 | 10998 | 39 | 434 |
| | Durum | 1.07 | 34 | 51 | 66 | 5.49 | 2.48 | 9.54 | 0.316 | 5431 | 44 | 363 |
| | Triticale | 1.23 | 42 | 59 | 80 | 5.09 | 3.83 | 10.1 | 0.412 | 8646 | 48 | 394 |
| 25.0 | LV | 0.99 | 33 | 50 | 67 | 5.91 | 2.69 | 7.07 | 0.384 | 6612 | 41 | 348 |
| | HV | 1.39 | 46 | 59 | 70 | 6.21 | 2.85 | 7.90 | 0.365 | 6760 | 43 | 358 |
| | Comm. | 0.83 | 31 | 43 | 60 | 6.19 | 3.21 | 8.32 | 0.397 | 8153 | 40 | 351 |
| | Durum | 0.67 | 24 | 38 | 54 | 5.01 | 2.18 | 5.71 | 0.386 | 4712 | 45 | 239 |
| | Triticale | 1.21 | 25 | 54 | 65 | 6.51 | 3.35 | 8.10 | 0.414 | 7173 | 49 | 266 |
| LSD | | 0.17 | 1 | 5 | 4 | 0.79 | 0.49 | 1.09 | 0.04 | 1202 | 1.7 | 44 |

The greater grain yields in the commercial wheats and triticale at wider row spacing reflected greater maturity biomass and harvest index. Whereas triticale produced fewer spikes and numbers of grains but larger grain size, while wheat varieties produced more grain but of smaller average size (Table 2).

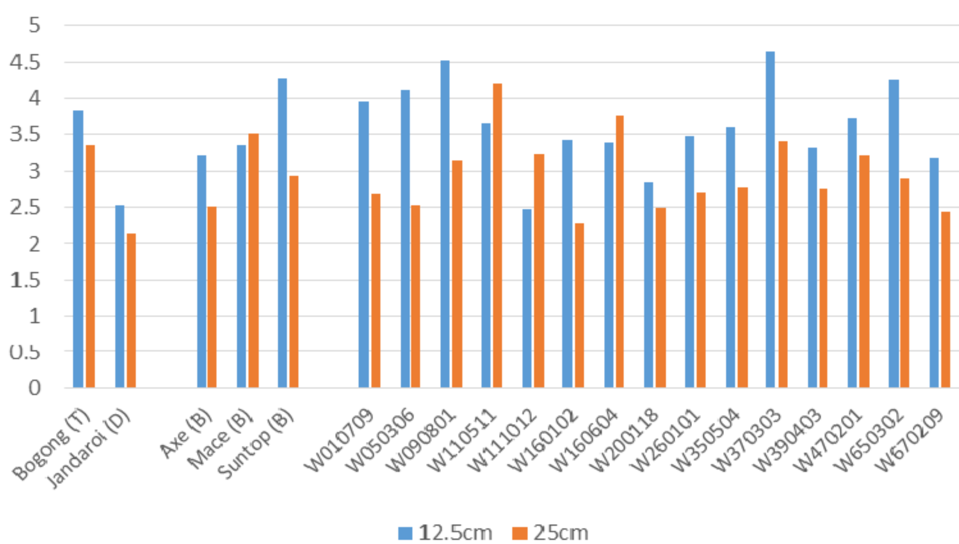


Figure 1: Grain yields (t/ha) for commercial triticale (T), durum (D), and bread (B) wheats, and a range of high- and low-vigour selected (W_) wheat germplasm evaluated in narrow (12.5cm) and wide (25cm) row spacings in two years at the Yanco Managed Environment Facility, Yanco NSW.

**Conclusions**

A clear understanding of the value proposition should underpin any long-term effort in breeding for new environments, new agronomic management or farming systems. The reduced vigour and conservative growth of current milling quality wheats may limit their potential and opportunities for greater biomass and yield to increase water productivity in no-till or stubble management systems utilising wide row spacing where crops are rainfed. Genes and low cost, high throughput selection methods are available to rapidly incorporate greater early vigour to improve performance in wide row sowings into commercial breeding programs.

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