## Trends in yielding ability and weed competitiveness of Australian wheat cultivars

**Rebecca Coleman** and Gurjeet Gill

Agronomy and Farming Systems, University of Adelaide, Roseworthy, SA 5371.
rebecca.coleman@adelaide.edu.au

### Abstract

Wheat breeding in Australia has undoubtedly resulted in large improvements in grain yield. This has been partly achieved through reduced plant stature, which may have compromised the ability of modern cultivars to compete with weeds. Fourteen cultivars released to Australian growers from 1860 to 1994, were grown in a field study at Roseworthy to determine whether there has been a systematic decline in weed competitive ability of wheat varieties over time. Oats (Cv. Marloo) were used as the weedy competitor in this study and were sown with the wheat to create paired weedy and weed-free plots.

A regression analysis of spatially adjusted mean wheat yield against the number of years since 1860 indicated a rate of increase of 16.6 kg/ha/year in yielding ability in the absence of weeds. The recently released cultivars, Spear, Excalibur and Frame suffered a greater yield loss due to weed competition but the actual yields in the presence of oats were still greater than that for the majority of older cultivars, except Gluyas Early, Nabawa and Gabo. Increased yield loss due to weed competition was associated with reduced plant height and light interception at early stem elongation ($P<0.05$). The newer varieties were consistently poor in suppressing weed growth and seed production. This decline in weed suppression was correlated with reduced early vigour (leaf 2 width; $P<0.05$) and plant height ($P<0.06$). The results clearly indicate that the improvements through plant breeding have increased the yielding ability of cultivars, but their ability to suppress weeds has been reduced. Competitive wheat cultivars have the potential to make a significant contribution to weed management but improvements in competitive ability need to be achieved through the incorporation of traits that do not compromise yielding ability.

### Keywords

Wheat cultivars, variation in weed competitive ability, crop yield loss, weed suppression

### Introduction

Plant breeding in association with improved management has been important in improving the yield potential of wheat. There have been numerous studies that have documented the rate of increase in grain yield in Australia (1, 2, 3) and overseas (4, 5). Much of this increase was associated with improved harvest index (6, 2, 5) and a greater number of grains per ear (2), following the development of semi-dwarf wheats, carrying *Rht-B1b* and *Rht-D1b* in the 1970s.

Prior to herbicides farmers relied on methods such as rotations, cultivation associated with later sowing and grazing to reduce weed infestation in the cropping phase. The 1940s saw the advent of selective herbicides to control broadleaf weeds, followed by pre- and post-emergent herbicides to control grass weeds in the 1960s. In the 1970s farmers began reducing cultivation and increasing herbicide usage to save fuel, labour and time. The development of herbicide resistance and environmental concerns surrounding the use of herbicides is necessitating the return to alternative forms of weed control including improving the competitiveness of the crop to reduce crop yield loss and suppress weed seed production. However, the modern wheat cultivars have been bred and selected under weed free conditions and appear to lack weed competitive ability. Lemerle *et al.* (7) found significant differences in the ability of Australian wheats to suppress weeds. The old, standard height wheats reduced *Lolium rigidum* dry matter more than the current semi-dwarf wheats.

### Materials and Methods

Fourteen cultivars and their date of release are described in Table 1. Many of the cultivars selected were widely grown in South Australia during the past century. The grain of the older cultivars was obtained from Mr Don Whiting, Barunga Gap, South Australia.

A field trial was conducted at Roseworthy, South Australia in 2001. The experiment was a strip-plot design with three replications. Oats (Cv. Marloo) were used as a weedy competitor in this study and were sown with the wheat to create paired weedy and weed-free plots. The approximate density of wheat and oats were 155 and 40 plants/m$^2$, respectively. A fungicide was applied to prevent rust infection at head emergence. Various morphological traits of the crop were measured and recorded during the growing season. All traits except grain yield and weed seed production were recorded in the weed-free plots only. These included length, width and area of leaf one, leaf two and the flag leaf, dry matter and light interception at early stem elongation, tiller number, height at maturity and time to anthesis. Length and width of the leaves was measured using a ruler and the leaf area estimated from the product of leaf length and width multiplied by 0.8 to correct for leaf shape (8). A LAI-2000 (LI-COR, USA) light interception probe was used to determine leaf area index (LAI) and percentage diffuse light penetration (DIFN). Grain yield was determined at maturity in the weedy and weed-free plots by harvesting with a small plot harvester. The oats were separated from the wheat using a seed grader with various sized sieves. The competitive ability of each wheat variety was determined by assessing the maintenance of grain yield in the presence of weeds and the suppression of weeds indicated by oat seed production. Analysis of variance was conducted on all data using GENSTAT 5 (9). The data was first analysed using a simple linear model and then re-analysed using a spatial model accounting for row and column effects (10). The spatially adjusted means were retained if the REML log-likelihood ratio tests indicated a significant improvement over the randomised complete block models.

**Results**

*Cultivar characteristics*

A sub-set of important crop traits is presented in Table 1. Significant differences occurred between the cultivars for several traits, including those associated with early vigour (width leaf 2 and LAI). As expected, older lines were taller, reaching over 130 cm but declined to around 100-110 cm in the modern cultivars. Apart from Purple Straw and Federation, cultivars flowered between 120-130 days after sowing.

**Table 1: Trait description of wheat cultivars.**

| Cultivar | Year of release | Length leaf 2 (mm) | Width leaf 2 (mm) | LAI | Height (cm) | Anthesis (days) |
|---|---|---|---|---|---|---|
| Purple Straw | 1860s | 140.9 | 3.61 | 2.28 | 121.1 | 150 |
| Gluyas Early | 1894 | 148.2 | 3.79 | 2.49 | 130.9 | 120 |
| Federation | 1901 | 109.7 | 3.61 | 1.53 | 115.5 | 139 |
| Nabawa | 1915 | 150.2 | 3.81 | 1.93 | 132.5 | 120 |
| Sword | 1923 | 155.5 | 3.87 | 1.88 | 136.0 | 127 |
| Ranee | 1924 | 131.1 | 3.53 | 1.83 | 126.3 | 127 |

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|---|---|---|---|---|---|---|
| Bencubbin | 1929 | 128.1 | 3.77 | 2.02 | 131.9 | 128 |
| Gabo | 1945 | 130.5 | 4.24 | 1.54 | 117.9 | 120 |
| Insignia 49 | 1951 | 131.7 | 3.56 | 1.65 | 108.0 | 126 |
| Halberd | 1969 | 137.2 | 3.83 | 2.00 | 111.5 | 125 |
| Warigal | 1978 | 132.1 | 3.61 | 1.36 | 96.3 | 126 |
| Spear | 1983 | 122.8 | 3.35 | 1.62 | 109.1 | 127 |
| Excalibur | 1991 | 127.7 | 3.90 | 1.78 | 98.9 | 122 |
| Frame | 1994 | 131.5 | 3.62 | 1.47 | 111.7 | 131 |
| LSD (P<0.05) | | 10 | 0.26 | 0.53 | 4.0 | 1 |

*Grain yield and competitive ability*

The regression analysis of grain yield against years since 1860 indicates a rate of increase in yield of approximately 16.6 kg/ha/year (Figure 1). There was a significant interaction (P<0.001) between the cultivar and presence or absence of weeds. The yield losses ranged from 11% for Nabawa to 40% for Spear and Warigal (Figure 2). An increase in yield loss was significantly correlated (P<0.01) with the year of introduction. However there was no systematic trend in weed suppression as indicated by the lack of significant correlation between the year of introduction and suppression of oat seed production. Cultivars that suppressed oats to the greatest extent were released between 1915 and 1945 (Figure 3).

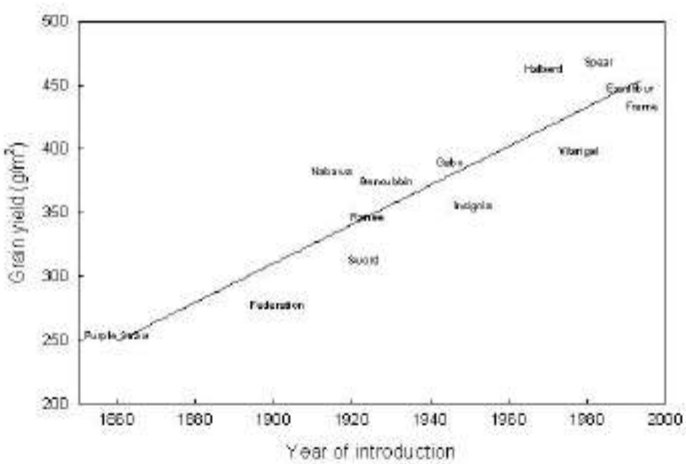

**Figure 1: The mean grain yield (g/m$^2$) (spatially adjusted) plotted against the year of introduction. y=240.16+1.66x ($r^2$=0.85, n=13), where y is the grain yield in g/m$^2$ and x is the number of years since 1860. The regression excludes Gluyas Early, which was an outlier with grain yield of 433g/m$^2$.**

*Correlations between morphological traits and competitive ability and year of introduction*

There was variation between cultivars for many of the morphological traits (P<0.01) (Table 1). Modern cultivars were found to have reduced light interception at early stem elongation, shorter flag leaves, reduced height and improved harvest index. Crop yield loss due to weed competition showed a significant negative correlation (P<0.05) with plant height at maturity and light interception at early stem elongation. Oat seed production was suppressed by cultivars with greater early vigour (leaf 2 width; P<0.05) and greater plant height (P<0.06).

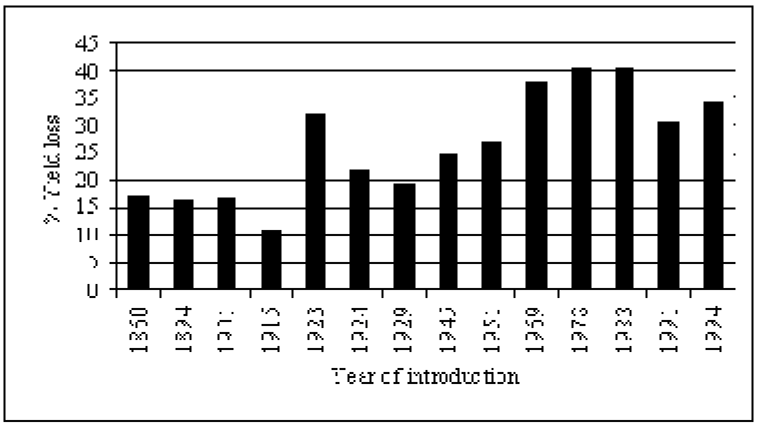


**Figure 2: The relationship between the year of introduction and percentage yield loss (calculated from the spatially adjusted grain yield in the presence and absence of weeds).**

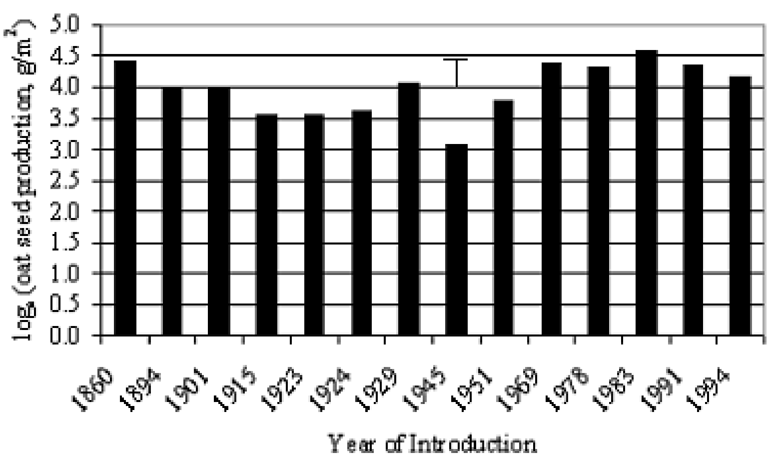


**Figure 3: The relationship between the year of introduction and oat (weed) seed production. The vertical bar represents the LSD (P<0.05).**

**Conclusion**

The study clearly demonstrated the improvement in grain yield through breeding effort over time, but also raised the issue of the unintended reduction in competitive ability of the modern cultivars. Even though modern cultivars have superior yields in the presence of weeds, they are unable to suppress weeds resulting in larger weed seed banks. The reduction in competitive ability was associated with reduced early vigour, lower light interception and the short stature of the semi-dwarf cultivars. When crop yield loss is used as the criterion, there is some evidence for a systematic decline in weed competitiveness of varieties over time. Although weed suppression differed significantly between wheat cultivars (ie. oat seed production), there was no systematic trend for this trait. The dwarfing genes in modern cultivars appear to have reduced their early vigour and light interception. To improve the competitive ability of modern cultivars, while maintaining their short stature, alternative dwarfing genes that are gibberellic acid (GA) sensitive and do not affect expression of early vigour need to be adopted.

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