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# Effect of variable crop duration on grain yield of irrigated spring-wheat when flowering is synchronised

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ABSTRACT

Short duration spring wheat cultivars are currently preferred for irrigated wheat production in subtropical Australia due to their high levels of lodging resistance. A study was conducted to determine whether recently developed lodging-resistant long duration cultivars could achieve increased grain yield compared to short duration cultivars in irrigated sub-tropical environments. A key aspect of the study methodology required the use of different sowing dates for each maturity group to ensure anthesis was synchronised and thus occurred during the same climatic conditions. Growth of representative cultivars in each experiment was simulated using the APSIM model to characterise each environment for the presence of water or nitrogen stress. Results of the study indicated that the long duration cultivars had an increased grain yield of 0.67 t $ha^{-1}$ (9.6%) on average across the 14 agro-climatic environments compared to the short duration cultivars. The response varied between agro-climatic environments, with long duration cultivars significantly higher yielding in 70% (or ten) of the environments, no significant difference observed in three environments, and a significantly lower yield associated with long duration cultivars in one environment. The yield advantage of the long duration cultivars was greater in environments where moderate water stress was experienced, with yield differences of up to 1.5 t $ha^{-1}$ observed in the most water-stressed environments. The yield advantage was less apparent in environments where low levels of water stress were experienced, and in two environments where lodging was more severe among the long duration cultivars. The relatively small difference in duration between the long and short duration cultivars in this study may not have fully exploited the potential benefits of longer duration cultivars. The results suggest that genetic improvement programs should continue to develop longer season germplasm that conveys an adaptive advantage to irrigated sub-tropical environments such as Australia, India and Mexico that experience short-term water deficits, and in which deficit irrigation is often the most profitable strategy for farmers. Additional research is necessary to determine whether ultra-long duration cultivars could further raise yield potential in sub-tropical environments if lodging could be avoided, through either genetic improvement or improved access to plant growth regulators.

## 1. Introduction

Spring wheat cultivars in subtropical Australia are often poorly adapted toirrigated production systems, due to increased lodging susceptibility of the long duration cultivars favoured in rainfed production systems (Peake et al., 2014, 2016a). This has constrained irrigated wheat production in the region to the use of a small number of short duration cultivars with high levels of lodging resistance, limiting yield potential to 8–9 t $ha^{-1}$ (Peake et al., 2014).

However, long duration cultivars are increasingly used in combination with early sowing dates to improve wheat yields in temperate, rainfed production systems of Australia (Coventry et al., 1993; Moore, 2009; Hunt et al., 2015; Flohr et al., 2018a). Early sowing of long duration cultivars is considered more likely to increase grain yield when lodging is prevented (Stapper and Fischer, 1990), and also when used in years with sufficient stored soil water and early season rainfall (van Rees et al., 2014). And although Hunt et al. (2015) did not observe yield benefits from growing longer duration cultivars in subtropical Australia, their subtropical rainfed environments were low yielding, experienced low rainfall, and may not have had sufficient yield

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potential to demonstrate the yield advantage often associated with early sown wheat.

The yield benefits associated with long duration cultivars in rainfed production systems have not yet been demonstrated in subtropical, irrigated spring wheat production systems. In a recently published irrigated study reporting experiments conducted between 1970 and 1975, Fischer (2016) found no difference in grain yield between sister lines varying for vegetative growth period, when sown on different dates to reach anthesis at the same time. Fischer (2016) also cited a range of irrigated studies that did not identify a yield advantage associated with early sowing of long duration cultivars (McDonald et al., 1983; Ortiz-Monasterio et al., 1994; Stapper and Fischer, 1990), while Coventry et al. (1993) and Gomez-Macpherson and Richards (1995) were also cited as examples of rainfed studies that produced similar results.

Close examination of these studies suggests that some may have generated results under nitrogen limited conditions. For instance, Gomez-Macpherson and Richards (1995) did not identify a grain yield advantage associated with long duration wheats that produced significantly greater biomass, however they only applied a maximum of 65 kg N ha$^{-1}$ to any of their experiments and did not test for soil N at sowing. Furthermore their grain protein contents were low (i.e. below 11%) except in their lowest yielding treatments, an indication that these treatments were limited by N deficiency (Goos et al., 1982; Holford et al., 1992). Additionally, it is now known that high yielding irrigated wheat crops in the subtropics have a nitrogen requirement in excess of 250 kg N ha$^{-1}$ (Ortiz-Monasterio, 2002), however McDonald et al. (1983) applied only 120 kg N ha$^{-1}$ to their experiments and did not present soil N or protein data, while Ortiz-Monasterio et al. (1994) conducted experiments on a low fertility soil with organic carbon of 0.5%, and applied 120 kg N ha$^{-1}$ to a soil which had 61 kg N ha$^{-1}$ at sowing. Insufficient N supply may have limited yield formation in the long duration cultivars in these studies, in which they produced significantly more biomass than short duration cultivars.

Finally, we suggest that the rainfed experimentation of Coventry et al. (1993) demonstrated a yield advantage associated with longer duration cultivars in their second season (1986), despite being used as an example to the contrary by Fischer (2016) presumably based on data from the first season (1985). Re-formatting of data from Coventry et al. (1993) to present yield and anthesis date on the same graph (Fig. 1) shows that while cultivars from each maturity group yielded similarly for the optimum anthesis dates in early October of 1985 (Fig. 1a), long duration cultivars had greater yield than the mid and short duration cultivars for the optimum anthesis date in mid-October 1986 (Fig. 1b).

Given the inconclusive results from the studies above, the recent identification of lodging-resistant long-duration cultivars in subtropical Australia has stimulated further interest in whether long-duration cultivars could increase grain yield in irrigated production systems in the region. This study therefore aims to determine whether newly released long duration cultivars with improved lodging resistance provide increased grain yield in comparison to short duration cultivars in irrigated, sub-tropical environments.

## 2. Methods

### 2.1. Experimental design

Grain yield of four long duration cultivars was compared with the grain yield of six short duration cultivars, with the long duration cultivars sown 2–3 weeks earlier than short duration cultivars in order to synchronise anthesis between the two groups (Tables 1, 2). Experiments were conducted at three locations in 2014 and 2015 (Emerald, Narrabri, Spring Ridge) and two locations in 2016 (Gatton, Spring Ridge) to represent diverse agro-climatic zones of sub-tropical, eastern Australia.

Due to the possibility that lodging and/or N limitation could affect experimental results, the cultivar comparisons were made on two different agronomic treatments at all locations and in all years. The first agronomic treatment (termed the 'Best Practice' treatment) was designed to minimise the risk of lodging through the use of canopy management techniques (Sylvester-Bradley et al., 1997, 2000), specifically by using in-crop N application (all years) and also the application

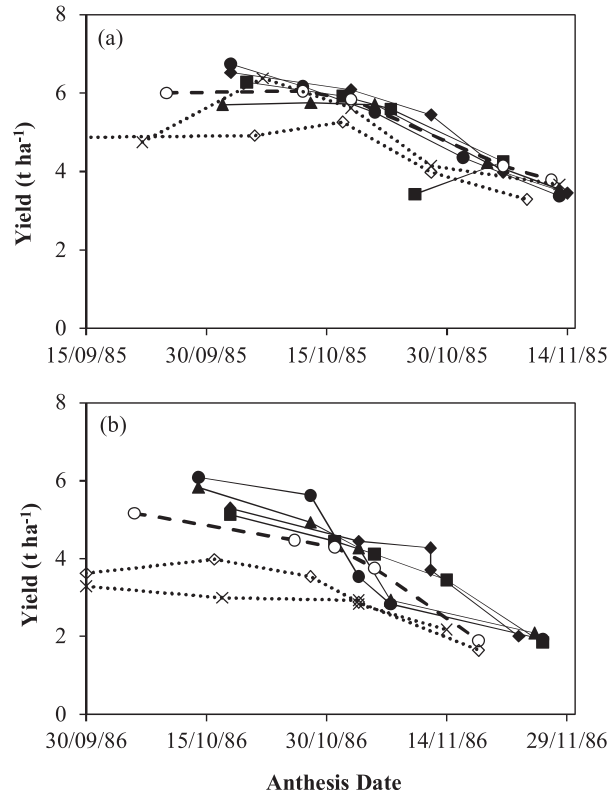


**Fig. 1.** Data from Coventry et al. (1993) combining anthesis date and grain yield into a single plot for each season, for four long duration cultivars (solid lines), one mid-duration cultivar (dashed line) and two short duration cultivars (dotted lines) across multiple sowing dates for their (a) 1985 and (b) 1986 experiments. Cultivars were Matong (◆—), Rosella (■—), Phoenix (●—), Osprey (▲—), Oxley (○ - - -), Millewa (×·······) and Mokoan (◊·······).

**Table 1**
Cultivars included in the early and late sown experiments for each location and year. An 'x' indicates that the cultivar was included in the common anthesis window for the sowing date and location of interest, for both the Sowing N and Best Practice agronomic treatments.

| Maturity Group, Cultivar | 2014 | | | 2015 | | 2016 | |
|---|---|---|---|---|---|---|---|
| | Emerald | Narrabri | Spring Ridge | Narrabri | Spring Ridge | Gatton | Spring Ridge |
| *Long Duration Cultivars* | | | | | | | |
| Lancer | x | x | x | x | x | x | x |
| Mitch | x | x | x | x | x | x | x |
| Sentinel | x | x | – | x | x | NS | NS |
| Trojan | x | – | – | x | x | x | x |
| *Short Duration Cultivars* | | | | | | | |
| Crusader | x | x | x | x | x | x | x |
| Dart | NS | NS | NS | x | x | x | x |
| Livingston | x | x | B | x | x | x | x |
| Merinda | x | – | B | x | x | x | x |
| Suntop | x | x | B | x | x | x | S |
| Wallup | x | x | x | x | x | x | x |

'S' or 'B' indicates the cultivar was included in the common anthesis window for only the Sowing N (S) or Best Practice (B) treatment at the relevant location/year. '–' indicates that the cultivar was outside the common anthesis window for both agronomic treatments. N.S. indicates the cultivar was not sown due to seed availability or quality issues.