Comparing flowering time and yield responses of wheat and barley

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Abstract
Whilst there has been some progress in defining optimal flowering periods for wheat, they have not been adequately defined for barley. Our understanding of the specific interactions between phenology and environment in barley, and the differences between the cereal species is limited. Time of sowing field experiments for wheat and barley were sown adjacently in two contrasting seasons at Wagga Wagga (2018) and Marrar (2019) in southern NSW and a comparative analysis conducted to determine differences in flowering time of barley, relative to wheat. The optimal flowering period, whereby yield was maximised for barley, was broader and earlier than for wheat in both seasons suggesting this is unlikely to be driven by frost tolerance alone. Barley had higher grain yields and accumulated more biomass compared to wheat, particularly at earlier flowering times indicating barley is better able to accumulate biomass during winter under low radiation and cool temperatures. This affirms there are differences in phenology, tolerance to abiotic stresses and yield physiology between wheat and barley and presents a management opportunity for growers in southern Australia.

Keywords
Phenology, biomass, frost, G × E × M

Introduction
Australian farming systems are evolving in response to a changing climate. The warming and drying of the climate in southern cereal production zones has occurred since the 1990s, and water-limited potential yields are influenced by the increasing threat of frost events and warmer spring temperatures (Hochman et al. 2017). The ability to match crop phenology with availability of resources, whilst minimising the risk of abiotic stress events during flowering and grain-filling underpins yield potential and crop adaptation (Richards 1991). In cereals, the onset and synchrony of development stages are largely determined through genetic responses to vernalisation and photoperiod. However, yield improvements have been achieved through direct selection of yield based on traditional May sowing dates and an appropriate flowering time, as such wheat and barley cultivars with a spring development pattern dominate southern Australian farming systems (Flohr et al. 2017; Porker et al. 2017). Currently there are few cultivars of wheat and barley suited to sowing early (e.g. slower developing spring or winter types with longer phase duration) in mid-low rainfall zones of the Australian cropping zone (Hunt, 2017) and breeders have indicated that any suitable new releases are 3-4 years away at least. In the meantime, growers in these environments are increasingly seeking options to exploit early sowing opportunities and are using quick spring cultivars of barley for this, due in part to its improved frost tolerance compared to wheat. Differences between the cereals species implies that there are either differences in phenology or tolerance to abiotic stress which influence the optimal flowering period whereby yield is maximised. There have been efforts made to determine the OFP for barley using simulation modelling, however these have not been validated under field conditions, with current development patterns and assumes the same parameters as for wheat (Lui et al. 2020). The aim of this study was to compare flowering and yield physiology of wheat and barley and to provide growers with information on when they should be sowing different crop species and cultivars in order to maximise yield and reduce risk of abiotic stresses.

Methods
Time of sowing field experiments of wheat and barley were sown adjacently at Wagga Wagga (2018) and Marrar (2019) in southern NSW. In both years, mean yields of wheat and barley were similar, despite seasonal conditions characterized by contrasting frost and heat stress events as described in Table 1 and Figure 1. For both species, a range of genotypes with varied phenology patterns, ranging from slow developing winter types to quick spring types were sown across sowing dates from early April to late May. The experiments were conducted as randomised split-plot designs (main plot: sowing date (SD); sub-plot:

genotype) with three replications. If the seedbed was too dry to allow emergence at targeted sowing time, plots were irrigated with ~10–15 mm of water applied using pressure compensating drip-line placed in seeding furrows to germinate seed and allow emergence. Target plant densities, fertiliser and all other crop management activities were implemented according to local district practice. A 1 m row was marked in all plots and assessed 2-3 times per week for flowering, which was determined when 50% of tillers in the marked row were observed to have extruded yellow anthers, or when anthers within the floret had changed from green to yellow. Biomass was sampled at flowering and grain yield attained via machine harvesting of the plots.

Table 1. Description of field experiments: mean wheat and barley yields, growing season rainfall (GSR) (Apr–Oct) and frequency of frost events (<2°C) and heat events (>30°C) during growing season (Apr–Oct) in 2018 and 2019.

Site (year)	Mean wheat yield (t/ha)	Mean barley yield (t/ha)	GSR (mm)	Frost events	Heat events
Wagga Wagga (2018)	1.86	3.52	135	37	12
Marrar (2019)	1.73	3.12	194	10	8

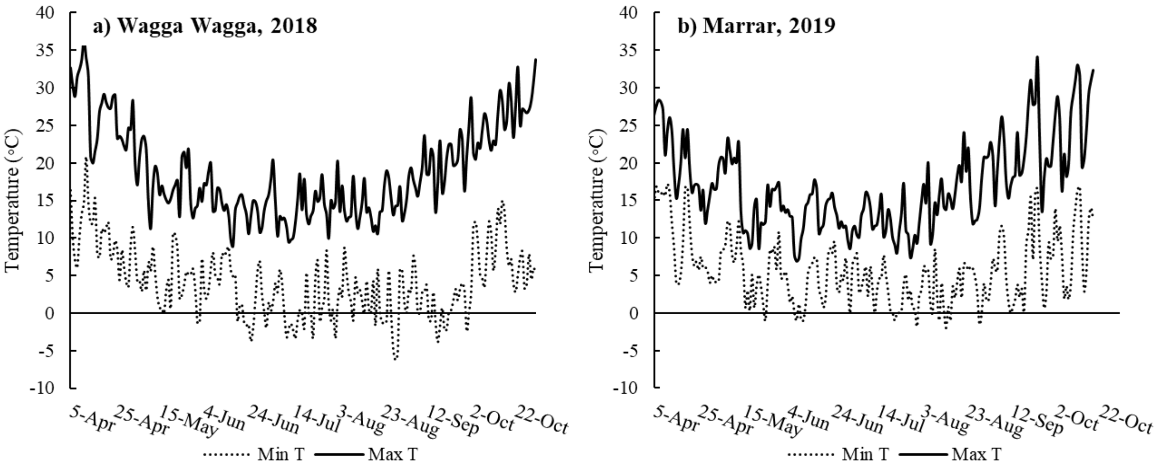

Figure 1. Daily minimum (Min T) and maximum (Max T) temperatures recorded at a) Wagga Wagga in 2018 and b) Marrar in 2019.

Results

Grain yields of barley were greater than wheat yields at earlier flowering times in both seasons (Figure 2). This suggests that barley is more adapted to earlier flowering and has less downside risk from early flowering compared to wheat. In 2018, under severe frost conditions, the optimal flowering period of barley was earlier than for wheat (Figure 2a), however the yield decline from later flowering in barley coincided with peak grain yield for wheat. In 2019, with minimal frost risk, high grain yields were achieved at an earlier flowering times in both species (Figure 2b), suggesting differences are unlikely to be driven only by greater frost tolerance of barley.

Barley also accumulated more biomass from sowing to flowering compared to wheat, notably at earlier flowering times at both sites despite contrasting seasonal conditions (Figure 3). This suggests that barley is better able to accumulate biomass during winter under low radiation and cool temperatures compared to wheat. The ability to flower earlier and accumulate biomass during winter may also have enabled barley to avoid drought stress in both seasons and contributed to the higher mean yields of barley compared to wheat. This also aligns with the suggestion that the critical period for grain number determination is slightly earlier for two-row barley than for wheat (Arisnabarreta and Miralles, 2008).

Implications

These findings present an opportunity for crop models to consider both the improved biomass accumulation and tolerance to frost in future simulations to derive optimal flowering periods for barley. Currently, barley genotypes are quick in comparison to wheat and growers do not have slower developing options suited to early sowing times, however, our data shows the risk associated with earlier sowing and flowering in barley is less than for wheat. As such, until slower developing wheat or barley cultivars are suitable for the low –

med rainfall zones of southern NSW, barley may offer some flexibility across a wider sowing window than current sowing recommendations.

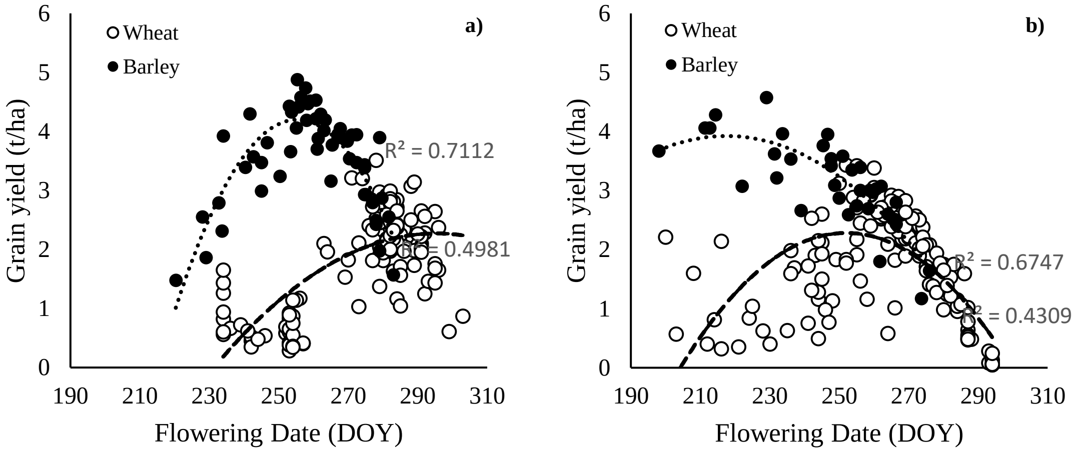

Figure 2. Relationship between flowering date (day of year, DOY) and grain yield of wheat and barley genotypes at a) Wagga Wagga, 2018 and b) Marrar, 2019.

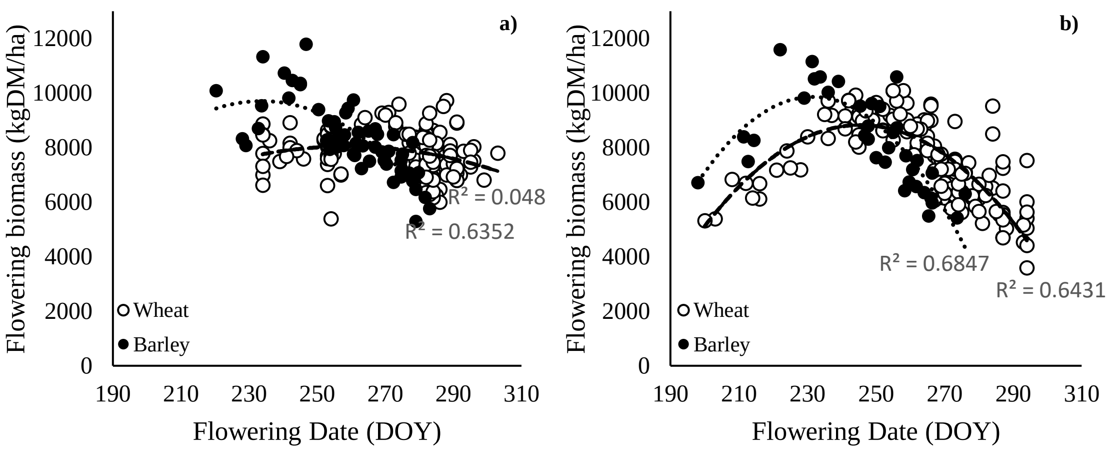

Figure 3. Relationship between flowering date (day of year, DOY) and accumulation biomass at flowering of wheat and barley genotypes at a) Wagga Wagga, 2018 and b) Marrar, 2019.

Conclusion

The flowering window whereby yield is maximised was earlier and broader in barley compared to wheat in two contrasting seasons. Barley was also capable of accumulating greater biomass under suboptimal winter temperatures and radiation. Understanding differences in phenology, frost tolerance and yield physiology between the cereal species presents an opportunity to improve future crop model predictions and provides information to growers in southern NSW to better understand and mitigate via species and genotype selection the risks associated with earlier sowing of cereals.

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