Management of early sown wheat: Development patterns of early sown wheat cultivars in the Mid-North of South Australia

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Abstract

Flowering time is a key determinant of wheat grain yield. As farm size increases, slow developing wheat cultivars enable growers to start sowing earlier, resulting in a greater proportion of the total sown area to flower during the optimal period. In 2017 an experiment consisting of nine cultivars and four times of sowing was established in Hart, South Australia, to assess the development and yield of newly released and unreleased winter and spring wheat cultivars. Due to its superior yield and stable flowering date, the long season winter cultivar Illabo was most adapted to the growing conditions at Hart from wide sowing windows (four weeks). All winter cultivars had stable flowering times (flowered within a 23 day period across all times of sowing), except for DS Bennett which flowered after the optimum period from early May sowing. While spring wheats sown at the optimal time were high yielding, yield and flowering dates were unstable over wide sowing windows with flowering dates spanning one month. The slow maturing spring cultivar LPB14-0392 also yielded well at Hart, although it does possess a unique development and flowering pattern that requires further investigation.

Keywords

Winter wheat, optimal flowering period, double ridge, yield stability, water stress

Introduction

Wheat production in South Australia currently accounts for 58% of the state's total winter crop tonnage (ABARES, 2018). Growers are sowing earlier in response to reduced autumn rainfall and increasing farm size (Flohr et al., 2018, Fletcher et al., 2016). Sowing date and cultivar development type influence the time at which wheat flowers, and are therefore important determinants for grain yield. Crops that flower too early have increased risk of frost damage, while crops that flower too late have an increased risk of exposure to higher temperatures and water stress. Crop development of wheat is under strong genetic control (e.g. temperature accumulation, photoperiod sensitivity, vernalisation sensitivity and earliness *per se* genes). The most widely grown cultivars in South Australia are mid-fast developing spring wheat cultivars that have limited photoperiod and vernalisation sensitivity, and rely on temperature accumulation alone for phenological progression (Eagles et al., 2009). If these cultivars are established prior to April 20 they are under unsatisfactory frost risk at flowering. Therefore, growers are restricted to a narrower window to sow their crop in order for it to flower during the optimal flowering period (OFP) (Flohr et al., 2017). In order to sow any earlier with success, growers need cultivars in which development is slowed by photoperiod or vernalisation (Hunt et al., 2019).Winter cultivars have a vernalisation requirement, meaning they need exposure to a period of cold temperatures in order to progress from a vegetative to a reproductive growth phase in their life cycle. Similarly slow developing spring cultivars have sensitivity to day length, where the transition to reproductive development is prolonged by short-day conditions (10 hr or less light) (Harris et al., 2016). This transition is signalled by the double ridge (DR) stage in wheat, marking the occurrence of floral differentiation. Following DR is the terminal spikelet (TS) stage, marking the completion of the spikelet initiation phase in wheat. Cultivars with suitable sensitivities to vernalisation and photoperiod that are adapted to early sowing in low to medium (<350 mm and 350-500 mm, respectively) annual rainfall environments in South Australia have not yet been identified.

The aim of this experiment was to explore the variation in crop development of newly released and unreleased slow developing wheats and identify the most suitable development types for the Mid North of South Australia.

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Methodology

An experiment was sown at Hart in 2017 as a split-block design containing four replicates of nine cultivars (Table 1), at four times of sowing [ToS (14th March, 31st March, 18th April and 3rd May)]. Cultivars were selected based on the differentiation of their development type from one another. Three plants were removed from each plot on frequent intervals in replicate one to determine their developmental growth stage and prepared for dissections using the protocols of Kirby and Appleyard (Kirby, 1984). The apical meristem was then examined under a digital Wi-Fi compound microscope (Leica ICC50 W). An image of the apex was taken and the development stage determined using the Waddington Scale (Waddington et al., 1983). Key floral development stages measured included the double ridge (DR) and terminal spikelet (TS) stages, while anthesis date was measured in the field when 50% of spikes in the plot had flowered. From 15 minute interval recordings of air temperature at the Hart Field-Site, cardinal air temperature and adjusted growing degree days [°Cd ($TT = \sum ((T_{min} + T_{max})/2) - T_{base})$] were calculated for each ToS, where T_{base} = 0°C, $T_{optimal}$ = 23°C and T_{max} = 37°C as per Flohr et al. (2018). Vernal days from sowing to DR were also calculated using T_{base} = -1.3°C, $T_{optimal}$ = 4.9°C and T_{max} = 15.7°C (Flohr et al., 2018, Porter and Gawith, 1999). The first three ToS were irrigated with the equivalent of 10 mm of rainfall post-sowing to ensure plant emergence would occur. All plots were mechanically harvested for grain yield. Grain yield is reported at 12.5% moisture.

Table 1. Categories of wheat cultivars based on their development type selected for the experiment at Hart in 2017.

Habit	Cultivar	Development Speed
Winter	DS Bennett	Slow-mid
	Illabo	Mid-fast
	Longsword	Fast
Spring	LPB14-0392	Slow
	Cutlass	Mid
	Trojan	Mid-fast
	Scepter	Fast

Results and Discussion

Analysis of sowing time and development

An annual rainfall of 330 mm was received at Hart in 2017, 191 mm of which fell during the growing season (April to October). This was considerably lower than the long term average of 407 mm of annual and 297 mm of growing season rainfall. Six frost events (temperatures reaching 0°C or below) were also recorded between the 18th and the 29th of August. Winter cultivars required a greater number of vernal days, but a lower number of calendar and accumulative degree day to reach DR at later ToS (Figure 1). This result is due to the vernalisation requirements of the winter cultivars saturating faster in the cooler minimum temperatures of winter, compared to autumn sowing dates. Genotypic differences were observed among the winter wheats in terms of their development at Hart. The calendar and growing degree days taken to reach DR and TS varied both between sowing dates and within cultivars. These results confirm that there is enough exposure to low temperatures at Hart to allow transition from the vegetative to reproductive growth phase in a range of cultivars. This allows the successful planting of fast to slow winter wheats across a range of autumn sowing dates at Hart.

The time to TS correlated with the time to flower in winter cultivars, whereas this is not the case in the spring types. For example, from May sowing dates Cutlass and Scepter reached TS at a similar time, but Cutlass flowered 12 days later than Scepter. This is likely due to the stronger photoperiod requirement of Cutlass extending the reproductive phase. It was also observed in the earlier ToS that the spikelet initiation phase (time between DR and TS) increased as the vegetative phase (time to DR) increased in all winter cultivars. The extension of the duration of spikelet initiation found among the cultivars with a vernalisation requirement may be influenced by their level of photoperiod sensitivity. However, Longsword a photoperiod insensitive winter wheat responded similarly to the photoperiod sensitive winter wheat DS Bennett, an observation that requires further investigation. This result could indicate these phases are not independent of each other or under another developmental control like earliness *per se* (Eps) genes. ToS had little influence on the length of the stem elongation phase in winter wheats, largely due to the modulation from vernalisation in previous development phases. Meaning the spike development phase was exposed to similar environmental conditions in both sowing scenarios. Cultivars also differed in length of the late spike development phase (time between TS and anthesis). Spring cultivars had a longer spike development phase compared to winter wheat.

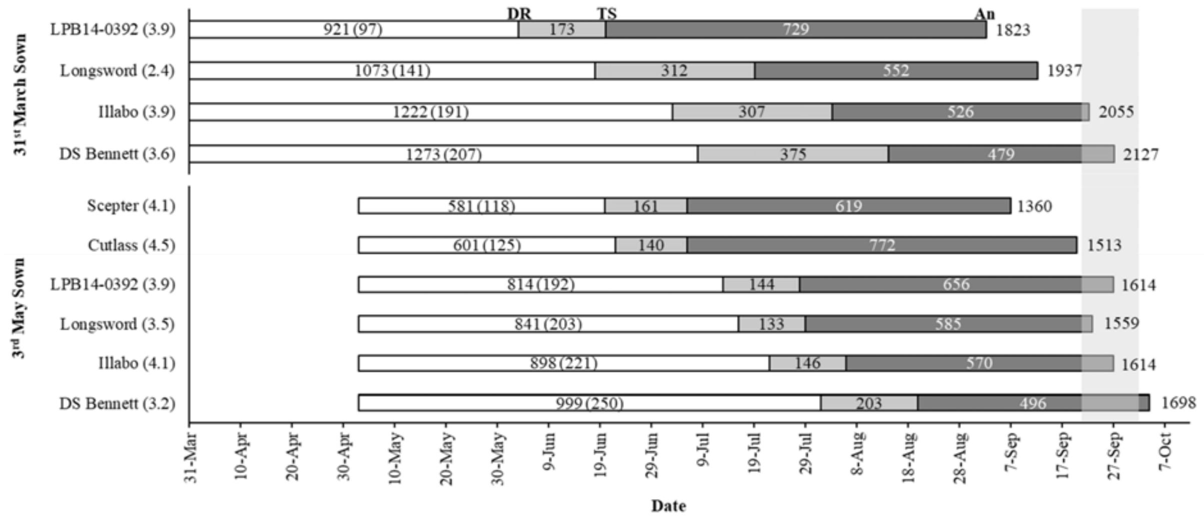

Figure 1. Developmental patterns of spring and winter wheat cultivars sown at Hart SA, in 2017. Numbers written in brackets next to the cultivar's name indicates yield in t/ha (LSD = 0.37). White area is calendar days from sowing to double ridge (DR), light grey area is calendar days from DR to terminal spikelet (TS) and the dark grey area is calendar days from TS to flowering (An). Number written without brackets inside graph is accumulative degree days °C and number written within brackets is vernal days to reach DR. Number at the end of the graph indicates total accumulative degree days °C to reach anthesis. Vertical light grey box is the optimal flowering period for Hart as per Flohr et al. (2017, defined as 21st September to 2nd October).

The mid-fast winter Illabo was able to flower during the OFP for Hart across the multiple ToS, whereas Longsword flowered too early from the early ToS and DS Bennett flowered too late from the later ToS. The photoperiod sensitive spring cultivar Cutlass also flowered too early from pre April 20 sowing (data not presented). The slow spring cultivar LPB14-0392 showed a unique development pattern. The temperature accumulation requirement for LPB14-0392 to reach DR was met at 921 degree days from early sowing, and 814 from the later sowing date. However, once reaching DR the spikelet initiation phase and stem elongation phase were extended. This cultivar also reached DR and flowering earlier than Illabo when sown early. In contrast, at the later sowing LPB14-0392 reached DR earlier and flowered later than Illabo. Despite these differences both LPB14-0392 and Illabo produced similar yields. This cultivars unique flowering behaviour and yield ability at Hart will require further research as its physiological requirements and response to environmental factors are not completely understood.

Grain Yield

The selected winter cultivars produced their highest yields in 2017 during the OFP for Hart (Flohr et al., 2017), whereas this period appeared to be too late for the faster maturing spring cultivars. The highest yielding cultivars sown on the 31st of March were LPB14-0392 and Illabo at 3.9 t/ha. However, both spring cultivars Cutlass and Scepter yielded 4.5 and 4.1 t/ha, respectively, when sown at their optimal sowing time (3rd of May). The slow maturing spring cultivar LPB14-0392 was able to maintain a yield of 3.9 t/ha when sown four weeks later. Early sowing of slower maturing cultivars were able to remain in a vegetative growth phase for a longer period than spring cultivars. This allowed for the development of a deeper root system to access stored soil moisture down the soil profile from the previous years and summer rainfall, and moisture closer to the surface when it became available later in the season (Lilley and Kirkegaard, 2016).

Conclusion

This data demonstrates breeders have developed winter wheats with an appropriate development pattern for earlier sowing at Hart in the Mid North of South Australia. Illabo appears to be the best adapted winter cultivar to growing conditions at Hart in the Mid-North region. This cultivar was able to maintain a stable flowering time close to the OFP, while also providing yield stability when sown in early – mid April. LPB14-0392 is another cultivar showing high yields from April sowing. Fast developing spring wheat

Scepter and photoperiod spring wheat Cutlass are not suited to pre April 20 sowing. The unique development pattern of LPB14-0392 suggests different combinations of crop development genes may allow for the use of spring types to explore earlier sowing opportunities than previously thought. This needs to be investigated further through additional experimentation across multiple growing seasons, in order to achieve a comprehensive analysis of these cultivars and others that may be suitable to the growing conditions at Hart.

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