Evaluating wheat, barley and oats for early sowing in frost prone landscapes in Western Australia Wickepin 2017 and 2018

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Abstract
Spring frosts can cause significant grain yield losses to cereals after head emergence. This trial examined the relative suitability of long, mid and short season wheat, barley and oats to early sowing in frost prone landscapes in WA at Wickepin in 2017-2018 with 4 sowing windows, . Trials were successful frosted in all seasons during the June to Oct; compared to wheat, oats and barley were less damaged by frost during flowering and grain fill and more profitable with early April sowing. With a mid-April sowing, Bannister oats achieved a higher grain yield and gross income compared to wheat and barley in 2017 and the highest yield and gross income of all sowing windows in 2018. With a late-May sowing, Bass barley achieved a higher grain yield and produced the highest gross income in frost-prone landscapes in 2017 and 2018. Sowing short-season wheat and barley varieties in April and late-April resulted in grain being either downgraded to feed and general-purpose milling in 2017 or having no commercial value at all in 2018. Wheat was not suitable for sowing in frost-prone landscapes relative to oats or barley but, of the wheat varieties evaluated, Forrest sown in mid-April in the high rainfall 2017 season (370mm GSR and early break) was competitive with barley and oats. Frost was not the only issue with early sowing, foliar disease pressure is also higher and contributed to yield decline along with frost particularly in Bass barley (leaf rust) and Durack oats (oat stripe blight) with mid- and late-April sowings in 2017. In Wickepin it is better to sow frost-prone areas in mid-April to early-May to long-season oats or in mid- to late-May to long- to mid-season barley varieties rather than sowing wheat.

Keywords
Frost, wheat, barley, oats, early sowing.

Introduction
In broad-acre cropping regions of Australia, frost risk is an important consideration for growers when implementing their cropping program. Estimates of the direct and indirect costs of frost vary across Australia. The cost of frost to the Western Australian (WA) wheat crop in 2016 was estimated to be 1.64 million tonnes or ~$410 million (GIWA 2017) across the WA cropping area. In WA since 1990s the average grower's cropping program has considerably increased in size. Sowing dates of wheat have shifted earlier, with a considerable proportion sown dry in most years to reduce heat and drought risk for the later part of the program. Conversely, in frost prone parts of the landscape, delaying sowing and/or using later maturing varieties has been the main agronomic approach to reduce frost risk. Late sowing (i.e. early June) reduces yield potential and increases heat and drought risk during flowering and grain filling. This paper reports on the results of two field trials located in frost prone areas of the Central WA wheatbelt in 2017 and 2018 and explores the relationship between sowing time, frost, cereal crop type and maturity.

Methods
This trial series examined the relative suitability of long, mid and short season wheat, barley and oats to early sowing in frost prone landscapes in Dale, Quairading, Wickepin, Lake Grace / Kulin, Western Australia in 2017 and 2018. In order of increasing maturity length within each crop type the trial comprised of 6 wheat varieties (Emu Rock[A], LRPB Trojan[A], Scepter[A], Cutlass[A], Forrest[A], LRPB Kittyhawk[A]/EGA Wedgetail), 3 barley varieties (La Trobe[A], Bass[A], Urambie) and 3 oat varieties (Durack[A], Kowari[A], Bannister[A]). The varieties were chosen based on their agronomic fit in Western Australia and to ensure a range of maturity types were compared. As maturity types were not replicated with multiple varieties, inferences about maturity groups within each crop type are confounded by the performance of that particular variety. The experiment had three sowing windows depending on irrigation capacity of seasonal rainfall; mid-April, late-April/early-May and late-May. Within each sowing window, a restricted randomization approach was used with varieties of each crop types (oats, wheat & barley) randomised to crop type blocks in a randomized lattice. Each sowing window comprises three replicates and each sowing window was considered a separate environment not a treatment per se. To monitor the differences in crop canopy effects on frost severity and duration, unshielded air temperature was measured at

canopy height. Temperature was logged every 15 minutes between early stem elongation (GS31) and crop maturity (GS87) in a reference variety in each of the three species (wheat-Scepter[A]; barley-La Trobe[A]; oats-Bannister[A]) in all three replicates in each sowing treatment. Temperature sensors were installed when the earliest maturing treatment was at GS31 and was increased in height in 100 mm increments fortnightly as the canopy grew to maintain +/- 100mm of the canopy boundary layer/flag leaf height. Tiny Tag Plus 2 (TGP-4017) loggers with internal temperature probes were used. Loggers were installed north facing with the internal temperature sensors facing upwards. Loggers were cable tied to a white, 50 mm diameter 1200 mm high polyvinyl chloride pipe in the middle of the plot. For the gross income analysis, gross income in $/ha was calculated as yield × grain price per tonne for average achieved classification based on CBH grain quality standards as at December 2017 or 2018. The grain price used was from CBH cash price (Kwinana Port) on the 20 December 2017 or 2018 was used. Where a treatment failed to meet export delivery standards a price of FED1 or OAT2 was discounted by $20/t if hectolitre was >50 kg/hL, or no commercial value if hectolitre was <50 kg/hL.

Results and Discussion

Seasonal conditions

The 2017 season at Wickepin had an early break and wet July and August (130mm) and an above-average growing season rainfall (GSR) of 370mm. Several moderate frosts occurred in late September and early October (Figure 1). All 2017 sowing dates established well without irrigation, however establishment was slightly lower in the earlier sowing windows (140 and 160 plants/m^2) than the latest sowing date (180 plants/m^2). In contrast, the 2018 season received below-average rainfall (total GSR 264mm) and had a late break on about 20-22 May. Two major and damaging frosts occurred on 15-16 September. The mid-April sowing window germinated well (140 plants/m^2), but early growth was hindered by wind damage and erosion, which resulted in furrow infill at the 1-2 leaf stage. In 2018 the late-April sowing window was deep sown into a drying soil profile and germination was staggered over the first week of May, consequently establishment was also slightly lower at ~100 plants/m^2. The last sowing window for 2018 was planted in late May into wet soil and established well (130 plants/m^2).

Mid-April 2017 and 2018

The long-season variety Bannister oats achieved the highest yield (Figure 1a and 2a) and gross income in the mid-April sowing at Wickepin in both the wet, early start of 2017 and the late dry season of 2018. Bannister's gross income for 2017 was $1,022/ha and $1,197/ha in 2018. The next highest incomes from this early-sowing window were achieved by Forrest wheat ($1010/ha in 2017) and Urambie barley ($961/ha in 2018). The barleys La Trobe ($955/ha) and Urambie ($915/ha) were not far behind in 2017. All these crops achieved high grain yields with minimal frost damage. However, in 2017 Bass barley suffered significant foliar disease (barley leaf rust and scald) and Durack and Kowari oats suffered oat strip blight (DPIRD diagnostic labs sample testing). In 2018 early-sown Bass and La Trobe barley suffered significant early grain-fill damage from frost (data not shown). As expected, the shorter-season wheats of Emu Rock, Scepter, LRPB Trojan and Cutlass suffered significant flower, head and grain frost and high floret sterility and low harvest index (data not shown) and were either unable to meet delivery standards or achieved only feed and general-purpose milling grades.

Late-April 2017 and late-April to early-May 2018

In the 2017 late-April sowing, Forrest wheat ($1,328/ha), La Trobe barley ($1,247/ha) and Bannister oats ($1,128/ha) achieved the highest gross incomes (Figure 1a. The short-season wheats were significantly frosted in the late-April sowing with high floret sterility and low harvest index (data not shown). Bass barley was again severely infected with foliar diseases and Durack oats with oat stripe blight and, as a result, both crops suffered reduced yields and low harvest indexes (data not shown). This increased disease pressure associated with earlier sowing highlights that frost is not the only risk to be managed with early sowing.

In 2018 the late April sowing was into marginal soil moisture and had staggered germination over the first week of May. This sowing window generated a different yield ranking compared to 2017. Bannister oats ($1,482), Bass barley ($1,422/ha) and the winter barley Urambie ($1,326/ha) were the three highest-yielding varieties (Figure 2b) and achieved among the highest gross incomes of the three sowing windows .
The shorter-season wheats Emu Rock, LRPB Trojan, Scepter, and Cutlass were just at or past head emergence and La Trobe barley was at early grain-fill and were all severely damaged by the frost events of

September 15-16. The dry September (6.6mm total rainfall) penalised the grain yield of the longer-season wheat varieties Forrest and EGA Wedgetail. While Forest avoided the frosts and still achieved the highest grain yield and gross income of all the wheats ($786/ha), this was only just over half the income generated by the longer-season barley and oats.

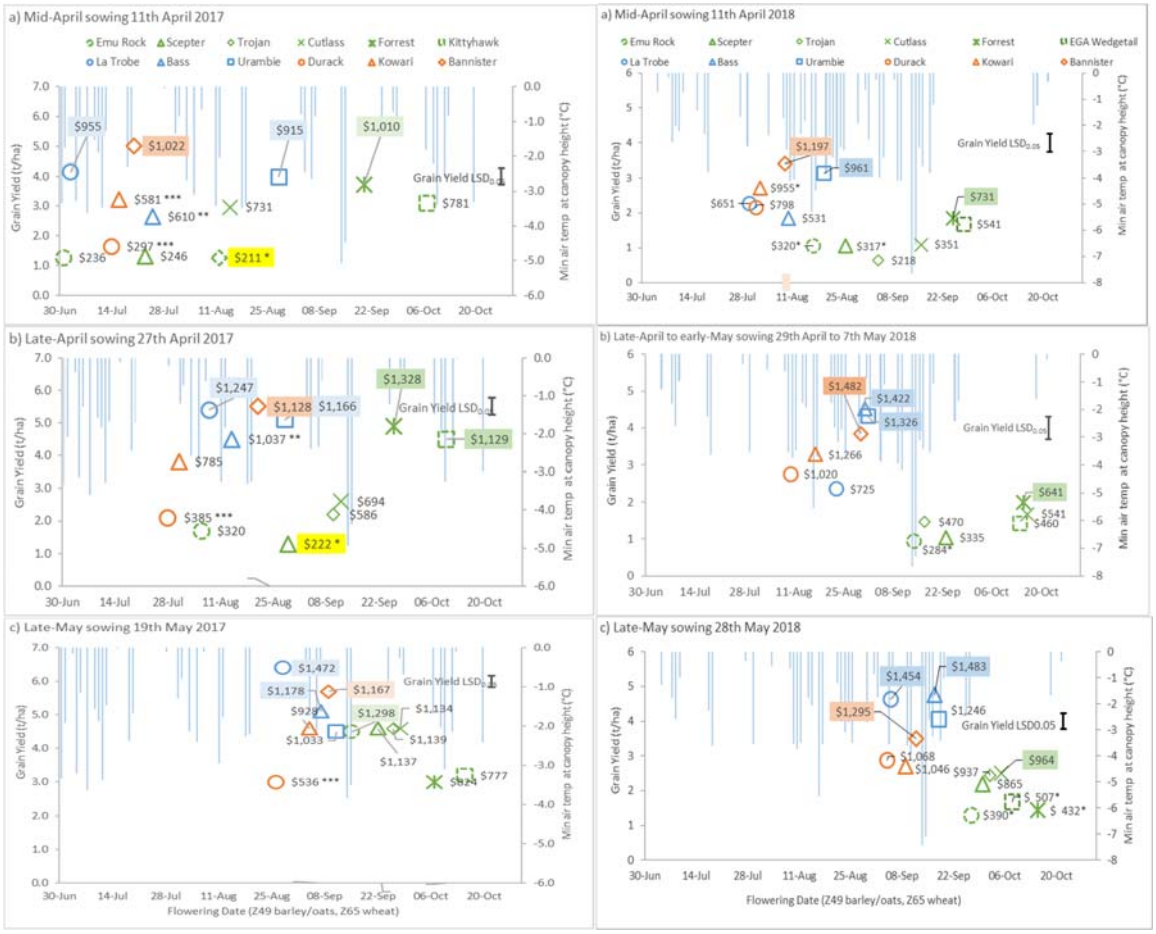

Figure 1 Wickepin 2017: interaction of flowering date, grain yield and gross income of barley, oats and wheat varieties when sown in (a) mid-April, (b) late-April and (c) late-May with June-September frost minimum temperatures (blue bars). Grain yield and flowering dates are the predicted means; n=3. $LSD_{0.05}$ for grain yield comparisons within crop type. *Failed to meet export delivery standards; price based on a $20 discount from FED1 or OAT2. **barley leaf rust *** oat stripe blight.

Figure 2 Wickepin 2018: interaction of flowering date, grain yield and gross income of barley, oats and wheat varieties when sown in (a) mid-April, (b) late-April and (c) Late-May with July-October frost minimum temperatures (blue bars). Grain yield and flowering dates are the predicted means; n=3. $LSD_{0.05}$ for grain yield comparisons within crop type. *Failed to meet export delivery standards; 'Seconds' price based on a $20 discount from FED1 or OAT2.

Late-May 2017 and 2018

Sowing La Trobe barley ($1,472) in late-May in 2017 generated the highest yield (Figure 1c) and gross income of all sowing windows (Figure 1). However, many crop varieties yielded well in 2017 with Emu Rock ($1,298/ha), Bass barley ($1,178/ha) Bannister oats ($1,167/ha) and Scepter, LRPB Trojan and Cutlass wheats (~$1,137/ha) all achieving high gross incomes. Durack oats was again impacted by oat stripe blight (visual observations) and the longer-season Forrest and Kittyhawk flowered too late to yield well (Figure 1c).

The late-May sowing in 2018 generated a similar yield and gross income ranking to the early-May sowing (Figure 2c. Bass ($1,483/ha), La Trobe barley ($1,454/ha) and Bannister oats ($1,295/ha) were the three highest yielding and gross income earners for this sowing window. La Trobe in this sowing window had

passed the vulnerable early grain-fill stage and was not impacted by frost. While significantly behind the barley and oats the best-yielding and highest gross-income wheat was Cutlass ($964/ha), and LRPB Trojan ($937/ha). Emu Rock, Forrest and EGA Wedgetail failed to make delivery standards due to low hectolitre and high screenings associated with frost (Emu Rock) and terminal stress (Forrest and EGA Wedgetail).

Conclusions

In conclusion, rather than sowing wheat it is better to sow frost-prone areas in mid-April through to late-April to longer-season oats such as Bannister or in mid-to-late-May to long to mid-season barley varieties with good disease management. Themost profitable wheat in frost-prone areas is for longer-season varieties with a strong photoperiod responsive variety such as Forrest sown in late April to early May, but only if subsoil moisture is good and the seasonal outlook is promising. If these conditions are not available or when sown after this period it is best to sow high yielding mid-long wheat varieties with mild photoperiod requirements such as Cutlass in late-May. These trials have highlighted the value of oats, barley and longer season wheat over short to mid-season wheats in maintaining higher gross incomes in frost prone parts of the landscape.

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