Management of early sown wheat: matching genotype to environment

Kenton Porker[1], James Hunt[2*], Felicity Harris[3], Sarah Noack[4], Michael Moodie[5], Kelly Angel[6], Michael Straight[7], Genevieve Clarke[6], Dylan Bruce[8], Ashley Wallace[9], Neil Fettell[10], Greg Brooke[11], Helen McMillan[10], Barry Haskins[12], Mick Brady[5], Todd McDonald[5], Brenton Spriggs[13], Sue Buderick[13], Darcy Warren[7].

[1] South Australian Research and Development Institute, Hartley Grove, Urrbrae SA 5064
[2] Department of Plant, Animal and Soil Sciences, La Trobe University, 5 Ring Rd, Bundoora VIC 3086
[3] NSW Department of Primary Industries, Wagga Wagga Agricultural Institute, Wagga Wagga NSW 2650
[4] Hart Field-Site Group, 155 Main North Rd, Clare SA 5453
[5] Frontier Farming Systems, 7B Byrne Ct, Mildura VIC 3500
[6] BCG, 73 Cumming Ave, Birchip VIC 3483
[7] FAR Australia, 4/97-103 Melbourne St, Mulwala NSW 2647
[8] South Australian Research and Development Institute, 70 Farrell Flat Rd, Clare SA 5453
[9] Agriculture Victoria, 110 Natimuk Rd, Horsham VIC 3400
[10] CWFS, 1 Fifield Rd, Condobolin NSW 2877
[11] NSW Department of Primary Industries, Trangie Agricultural Research Centre, PMB 19, Trangie NSW 2823
[12] AgGrow Agronomy & Research, 7 Francine Ct, Yoogali NSW 2680
[13] South Australian Research and Development Institute, McKenzie Rd, Minnipa SA 5654
*Presenting author; j.hunt@latrobe.edu.au

Abstract
Australian wheat breeding programs have responded to the need for cultivars better suited to early sowing and have begun releasing a new generation of winter wheats. However, it is not known which of the new cultivars are best adapted to different environments across the wheat belt, or over what period they can be established and still achieve yields competitive with spring wheats sown in their optimal window. We grew four new winter cultivars and four elite spring checks in experiments with four times of sowing (mid-March, early-April, mid-April, early-May) in 11 different environments across SE Australia during 2017 and 2018. We found that yield of the best winter wheats was comparable with spring wheats sown in their optimal window. Due to the stable flowering time of winter cultivars, adaptation was driven by cultivar flowering time and coincidence with optimal flowering periods in the different environments. The fast winter cultivar Longsword tended to yield best in low yielding (<2.5 t/ha) environments with an early flowering window. The mid-slow winter cultivar DS Bennett yielded most in higher yielding environments (>2.5 t/ha) with a later flowering window, apart from the Mid North of SA where the mid-fast cultivar Illabo was superior. Highest yields of winter wheats were achieved when sown during April and declined when sown in either mid-March or early May.

Key Words
Winter wheat, development, flowering, vernalisation.

Introduction
Winter wheats adapted to the medium and low rainfall zones of southern Australia could substantially increase whole farm yields by allowing sowing to start earlier and thus more crop area to be sown on time (Hunt *et al.* 2019). Maintenance of yield at early sowing times is due to the stable flowering behaviour of winter wheats conferred by obligate vernalisation requirement (Flohr *et al.* 2018), which can also help reduce frost damage from accelerated flowering in a warming climate (Hunt *et al.* 2018). Winter wheats are also highly suited for dual purpose grazing during vegetative development, and their use in mixed farms can substantially increase profitability (Hunt 2017). Breeding companies have responded to this opportunity and a new generation of winter wheats have been released from 2016 onward that have potential adaptation to regions of the cropping belt beyond those that have traditionally used them (i.e. higher rainfall areas of SE NSW and SW Victoria). The aim of this study was to evaluate yield of the new cultivars across the south eastern Australian cropping belt, with emphasis on low to medium rainfall zones of SA & VIC that have not previously had access to adapted cultivars. As winter wheats have been rarely grown in these environments before, a secondary aim was to determine the optimal timing of establishment for high yields. This study was part of a larger project that also evaluated complementary management practices to maximise yields (Porker *et al.* 2019, in these conference proceedings), amounts of soil water required for successful establishment (Clarke *et al.* 2019, in these conference proceedings) and phasic development of the new generation of winter cultivars (Bruce *et al.* 2019, in these conference proceedings).

Methods

Eleven field sites were chosen to be representative of the major medium-low rainfall environments in which wheat is grown in SE Australia (Table 1). Sites were in elevated positions in the landscape, except for Loxton, Horsham and Yarrawonga which were either in hollows or flats so they experienced realistic frost conditions in these frost prone locations. At each site, a core set of 4 new or pre-release winter cultivars and 4 spring cultivars (Table 2) were planted at either 3 (NSW sites) or 4 (SA & VIC sites) times of sowing in randomised split-plot complete block or row:column designs with time of sowing as the main plot and cultivar as the sub-plot. Each treatment was replicated 4 times. At all sites if the seedbed was too dry to allow emergence, plots were irrigated with ~10 mm of water applied using pressure compensating drip-line placed in seeding furrows to germinate seed and allow emergence. Targeted times of sowing in VIC & SA experiments were 15 March, 1 April, 15 April, 1 May and in NSW the last three of these dates. All sites were sown within 5 days of the target dates. Experiments were analysed individually using either ANOVA (for randomised split-plot complete block experiments) or mixed linear models (for split-plot row:column experiments) with time of germination and cultivar as factors/fixed effects and block structure as random effects. For the purposes of analysis, yield of winter cultivars was compared to yield of the elite spring cultivar Scepter at the last (~1 May) time of germination as a current best-practice control. Experiments in VIC & SA were analysed within two yield environment groups (yield of Scepter above or below 2.5 t/ha) using mixed linear models with time of germination and cultivar as fixed effects and site as a random effect.

Table 1. Location of field experiments, average annual rainfall, summer fallow (Nov-Mar) and growing season rainfall (Apr-Oct) in year of the experiments.

Site	Station number & years of record	Mean annual rainfall (mm)	2016-2017 Nov-Mar rainfall (mm)	2017 Apr-Oct rainfall (mm)	2017-2018 Nov-Mar rainfall (mm)	2018 Apr-Oct rainfall (mm)
1. Minnipa SA	18195 (1997-2018)	277	138	141	62	186
2. Booleroo SA	19006 (1883-2018)	392	177	165	116	132
3. Hart SA	21007 (1897-2018)	406	165	192	118	160
4. Loxton SA	24013 (1896-2018)	261	120	135	83	92
5. Mildura VIC	76031 (1947-2018)	288	96	134	106	94
6. Birchip VIC*	77008 (1891-2018)	354	143	215	75	138
7. Horsham VIC	79100 (1998-2018)	368	121	303	83	211
8. Yarrawonga VIC	81124 (1994-2018)	469	140	276	161	135
9. Wallendbeen NSW	73043 (1914-2018	686	229	279	-	-
10. Rankins Springs NSW*	75146 (1969-2018)	398	-	-	145	122
11. Wongarbon NSW	65099 (2003-2018)	578	284	170	-	-

Table 2. The core set of cultivars and breeding lines used in field experiments.

Cultivar	Release year	Company	Habit	Development speed
DS Bennett	2018	Dow	Winter	Mid-slow
Kittyhawk	2016	LRPB	Winter	Mid
Longsword	2017	AGT	Winter	Fast
Illabo	2018	AGT	Winter	Mid-fast
LPB14-0392	2019	LRPB	Spring	Very slow
Cutlass	2015	AGT	Spring	Mid
Trojan	2013	LRPB	Spring	Mid-fast
Scepter	2015	AGT	Spring	Fast

Results and discussion

Yield of the highest yielding winter cultivar was not significantly ($P<0.05$) different to Scepter sown at its optimal time at sixteen out of twenty sites, significantly greater in three and significantly less at one (Figure 1, Table 3). Yield of the highest yielding winter wheat was not significantly different to the highest yielding slower developing spring cultivar at fourteen sites, significantly greater at four and significantly less at two sites (Figure 1, Table 3). Three winter cultivars were consistently highest yielding; Longsword, Illabo and DS Bennett (Table 3). Which of these cultivars was highest yielding depended on cultivar development speed, the timing of the optimal flowering period in a given environment (Flohr *et al.* 2017) and the severity and timing of frost. The fast winter cultivar Longsword performed best at low yielding sites (<2.5 t/ha) with early optimal flowering periods (Table 3, Figure 2). The mid-slow cultivar DS Bennett performed best in higher yielding sites (>2.5 t/ha) with later optimal flowering periods (Table 3, Figure 2), although the mid developing cultivar Illabo yielded highest at all sites in the Mid North of SA (Table 3). DS Bennett also yielded highest at low yielding sites that experienced severe stem- or reproductive frost (Table 3). DS Bennett has the longest vegetative phase of cultivars tested (Bruce *et al.* 2019, this conference proceedings) which reduces exposure to stem frost, and it frequently achieved high yields from relatively late flowering dates (data not shown). These traits make DS Bennett potentially useful for managing frost risk in frost prone landscapes of the medium and low rainfall zones. This is achieved through late flowering, but without lowering biomass production and yield potential as happens if later flowering is achieved by delayed sowing of spring wheats. The poor yields of Longsword relative to other cultivars in higher yielding environments (Figure 2) was explained by a combination of flowering too early and having inherently greater floret sterility (mean=29%) than other cultivars (e.g. Illabo mean=12%) irrespective of flowering date.

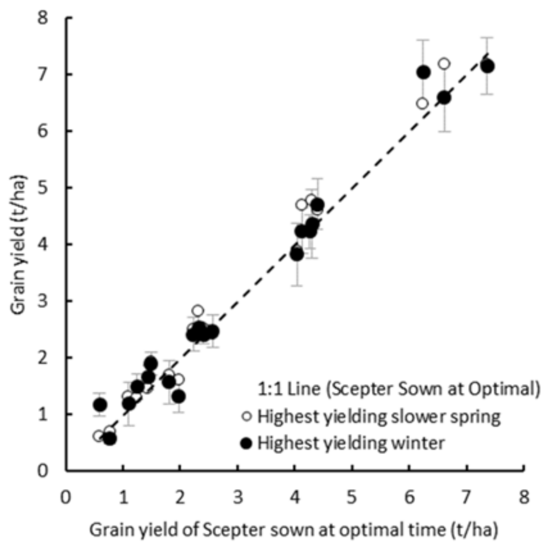

Figure 1. Grain yield of Scepter sown at its optimal time (~1 May) at the 20 site years compared to the highest yielding winter wheat (●) and highest yielding slower developing spring (○). Error bars indicate LSD (P<0.05).

Table 3. Mean grain yield of the highest yielding winter and slower spring cultivars in comparison to Scepter sown at the optimum time (~1 May). Different letters within a site indicate significant differences in grain yield.

Site	Year	Grain yield of Scepter sown ~1 May (t/ha)		Highest yielding winter cultivar: Grain Yield (t/ha)		Cultivar	Germ Date	Highest yielding slower spring cultivar: Grain Yield (t/ha)		Variety	Germ Date
Yarrawonga*	2018	0.6	a	1.2	b	DS Bennett	16-Apr	0.6	a	Cutlass	16-Apr
Booleroo	2018	0.8	a	0.6	a	Longsword	4-Apr	0.7	a	Trojan	2-May
Loxton	2018	1.1	a	1.2	a	Longsword	19-Mar	1.3	a	Cutlass	3-May
Minnipa	2018	1.3	a	1.5	b	Longsword	3-May	1.3	a	Trojan	3-May
Mildura*	2018	1.4	a	1.7	b	DS Bennett	1-May	1.5	a	LPB14-0392	1-May
Mildura	2017	1.5	a	1.9	b	Longsword	13-Apr	1.9	b	Cutlass	28-Apr
Horsham*	2018	1.8	a	1.6	a	DS Bennett	6-Apr	1.7	a	Trojan	2-May
Booleroo	2017	2.0	a	1.3	b	DS Bennett	4-May	1.6	b	Cutlass	4-May
Minnipa	2017	2.2	a	2.4	a	Longsword	18-Apr	2.5	a	Cutlass	5-May
Loxton	2017	2.3	a	2.6	a	Longsword	3-Apr	2.8	b	LPB14-0392	3-Apr
Hart	2018	2.4	a	2.4	a	Illabo	17-Apr	2.5	a	LPB14-0392	17-Apr
R. Springs	2018	2.6	a	2.5	a	DS Bennett	19-Apr	2.4	a	Trojan	7-May
Birchip	2018	4.0	a	3.8	a	Longsword	30-Apr	3.9	a	Trojan	30-Apr
Hart	2017	4.1	a	4.3	a	Illabo	18-Apr	4.7	b	LPB14-0392	18-Apr
Yarrawonga*	2017	4.3	a	4.2	a	DS Bennett	3-Apr	4.3	a	Cutlass	26-Apr
Wongarbon	2017	4.3	a	4.4	a	DS Bennett	28-Apr	4.8	a	Trojan	13-Apr
Tarlee	2018	4.4	a	4.7	a	Illabo	17-Apr	4.6	a	LPB14-0392	17-Apr
Wallendbeen*	2017	6.2	a	7.1	b	DS Bennett	28-Mar	6.5	a	Cutlass	1-May
Birchip	2017	6.6	a	6.6	a	DS Bennett	15-Apr	7.2	a	Trojan	15-Apr
Horsham*	2017	7.4	a	7.2	a	DS Bennett	16-Mar	7.2	a	Trojan	28-Apr

*stem and/or reproductive frost substantially affected yield

The specific adaptation of winter cultivars with different development speeds to different flowering environments corroborates previous studies using near-isogenic lines (Hunt *et al.* 2019). This is because flowering time in winter cultivars cannot be manipulated by varying sowing time as it can in spring cultivars, and therefore different winter cultivars with appropriate development patterns are required to achieve optimal flowering periods in different environments.

The highest yields for winter wheats generally came from germination dates in the month of April (Table 3). Yields tended to decline when sowing moved into March or early May (Figure 2). Slower developing spring cultivars achieved highest yields from sowing dates after April 20, and yielded less than the best performing winter cultivars when sown prior to April 20 (data not shown).

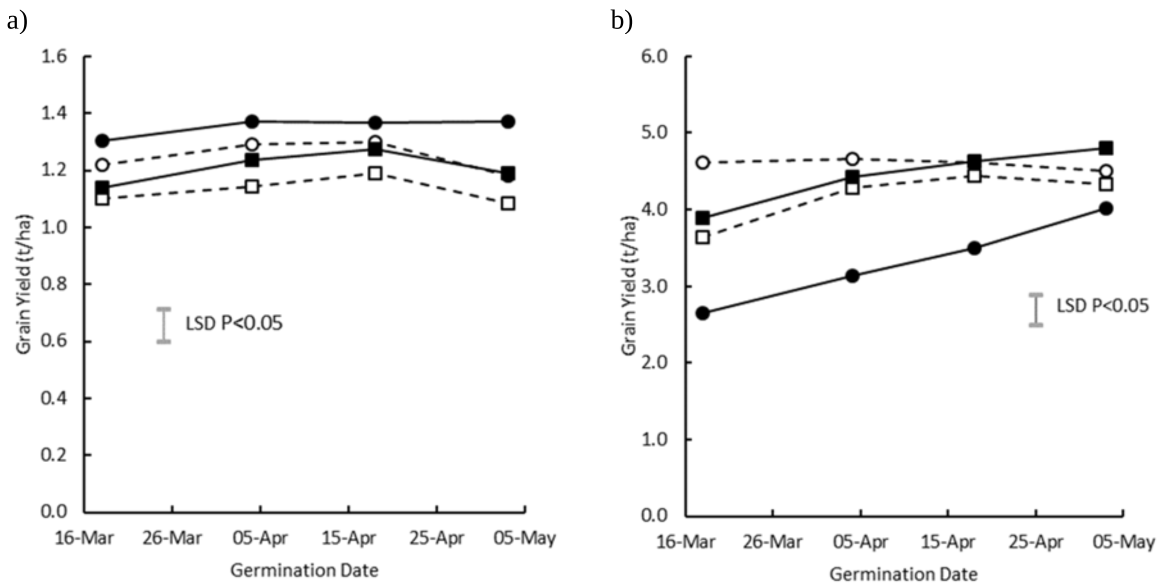

Figure 2. Mean grain yield for Longsword (●), DS Bennett (○), Illabo (■) and Kittyhawk (□) across four times of sowing from all SA & VIC sites where Scepter yielded a) less (n=11) or b) greater (n=5) than 2.5 t/ha.

Conclusion

If sown during April, new winter cultivars can match yields of elite spring cultivars across a broad range of environments in SE Australia. Because flowering time of winter cultivars is relatively insensitive to sowing date, different winter cultivars with appropriate development speed are required to maximise yield in different flowering time environments. Breeding programs will need to target development patterns to suit different flowering time environments – fast winter for warm, low rainfall environments and mid to mid-slow for cool medium rainfall environments.

Acknowledgements

This research was made possible by GRDC investment through project number 9175069.

References

Flohr, BM, Hunt, JR, Kirkegaard, JA, Evans, JR (2017) Water and temperature stress define the optimal flowering period for wheat in south-eastern Australia. *Field Crops Research* **209**, 108-119.

Flohr, BM, Hunt, JR, Kirkegaard, JA, Evans, JR, Trevaskis, B, Zwart, A, Swan, A, Fletcher, AL, Rheinheimer, B (2018) Fast winter wheat phenology can stabilise flowering date and maximise grain yield in semi-arid Mediterranean and temperate environments. *Field Crops Research* **223**, 12-25.

Hunt, JR (2017) Winter wheat cultivars in Australian farming systems: a review. *Crop and Pasture Science* **68**, 501-515.

Hunt, JR, Hayman, PT, Richards, RA, Passioura, JB (2018) Opportunities to reduce heat damage in rain-fed wheat crops based on plant breeding and agronomic management. *Field Crops Research* **224**, 126-138.

Hunt, JR, Lilley, JM, Trevaskis, B, Flohr, BM, Peake, A, Fletcher, A, Zwart, AB, Gobbett, D, Kirkegaard, JA (2019) Early sowing systems can boost Australian wheat yields despite recent climate change. *Nature Climate Change* **9**, 244-247.