Using time of sowing of wheat and pre-emergent herbicides to control annual ryegrass (*Lolium rigidum*)

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Abstract
Trials were conducted to investigate the interaction between time of sowing in wheat and pre-emergent herbicide over 3 years at Hart, SA. The delay in sowing time was between 27 days in 2015 and 43 days in 2016. In two of the three years, grain yield was significantly higher in the earlier time of sowing. In 2016 a higher wheat yield was obtained with the later time of sowing. In 2014 and 2015 there was no significant difference in annual ryegrass numbers in crop between the two times of sowing; however, there were significant effects of the pre-emergent herbicides. In 2016, there was a significant herbicide x time of sowing interaction. There was a significant herbicide treatment by time of sowing interaction in all years for annual ryegrass spike production. In the nil herbicide treatment there were significantly more annual ryegrass spikes in the first time of sowing in one of the three years, but no difference between times of sowing where pre-emergent herbicides were used. Early sowing with effective pre-emergent herbicides provided effective control of annual ryegrass and limited seed production to no more than observed with later sowing and may be a more profitable option due to increased grain yield.

Keywords
Competition, pre-emergent herbicide, time of sowing, weed control.

Introduction
It has been traditional advice to delay sowing in weedy paddocks in order to maximise weed control prior to sowing (Forcella et al. 1993; Gill and Holmes 1997; Melander et al. 2005). However, recent changes to farming systems and the availability of new pre-emergent herbicides have resulted in questions about whether this remains the best strategy. No-till seeding has meant that crops can be planted earlier taking better advantage of water availability (Derpsch et al. 2010). In addition, wheat planted into warmer soil grows more strongly offering a competitive advantage against weeds (Gomez-Macpherson and Richards 1995).

Earlier sowing may mean more weeds are present in crop. However, in continuously cropped paddocks there has been an increase in dormancy in key grass weeds (Kleemann and Gill 2006; 2013; Fleet and Gill 2012) and there is evidence for some increase in dormancy in annual ryegrass (*Lolium rigidum*) (Chauhan et al. 2006). If less of the weed population emerges prior to sowing, there is less advantage in delaying sowing for weed control.

Annual ryegrass across South Australia has evolved extensive resistance to all post-emergent herbicides used in cereal crops (Boutsalis et al. 2012). This means that pre-emergent herbicides are now the main method of control in wheat. New pre-emergent herbicide options for annual ryegrass have also given greater flexibility for the control of annual ryegrass in wheat (Boutsalis et al. 2014). This research was conducted to investigate the effect of wheat time of sowing on the control of annual ryegrass with pre-emergent herbicides.

Methods
Trial design and herbicide treatments
A series of 3 trials were conducted at Hart in SA between 2014 and 2016. Across three seasons the efficacy of pre-emergent herbicides on ryegrass was examined in combination with time of sowing. To ensure even annual ryegrass establishment across the trial site seed was broadcast the year prior to trial establishment at a rate of 25 kg ha^{-1}. Prior to seeding an additional 5 kg ha^{-1} ryegrass seed was spread and lightly tickled in. The trial was a split-plot design with one wheat cultivar (Scout 2014, Estoc 2015, Mace 2016), two times of sowing and six pre-emergent herbicides (Table 1).

Table 1. Herbicide treatments used in each year of the trial. All herbicides were applied IBS, except for the second application of prosulfocarb + S-metolachlor in 2014.

Treatment no	Pre-emergent herbicide and rate in g a.i. ha^{-1} (Product names in parentheses)		
	2014	2015	2016
1	Nil	Nil	Nil
2	Prosulfocarb 2000 + S-metolachlor (Boxer Gold)	Prosulfocarb 2000 + S-metolachlor (Boxer Gold)	Prosulfocarb 2000 + S-metolachlor (Boxer Gold)
3	Pyroxasulfone 100 (Sakura)	Pyroxasulfone 100 (Sakura)	Pyroxasulfone 100 (Sakura)
4	Prosulfocarb 1600 + S-metolachlor (Boxer Gold) + triallate 1000 (Avadex Xtra)	Prosulfocarb 1600 + S-metolachlor (Boxer Gold) + triallate 1000 (Avadex Xtra)	Prosulfocarb 1600 + S-metolachlor (Boxer Gold) + triallate 1000 (Avadex Xtra)
5	Pyroxasulfone 100 (Sakura) + triallate 1000 (Avadex Xtra)	Trifluralin 720 (TriflurX) + triallate 1000 (Avadex Xtra)	Trifluralin 720 (TriflurX) + triallate 1000 (Avadex Xtra)
6	Prosulfocarb 1600 + S-metolachlor (Boxer Gold) fb* Prosulfocarb 1200 + S-metolachlor (Boxer Gold)	Prosulfocarb 2400 (Arcade)	Prosulfocarb 2400 (Arcade)

*fb = followed by

Dates of sowing were 4th May (TOS 1) and 2nd June 2014 (TOS 2), 30th April (TOS 1) and 27th May 2015 (TOS 2), and 20th April (TOS 1) and 2nd June 2016 (TOS 2). In each year a pre-sowing knockdown application of glyphosate (1350 g a.e. ha^{-1}) + oxyfluorfen (18 g a.i. ha^{-1}) was applied to control emerged weeds prior to each sowing date. This means TOS 2 had two knockdown herbicide applications prior to sowing. Growing season rainfall (April to October) was 280 mm in 2014, 230 mm in 2015 and 356 mm in 2016.

Pre-emergent herbicides were incorporated by sowing (IBS) within a few hours of application. Post sowing Boxer Gold was applied at the 2-3 leaf crop growth stage. Annual ryegrass control (plant and spike number), and wheat grain yield and quality were assessed each season.

Statistical analysis

Data was analysed by two way ANOVA with herbicide treatments and time of sowing as factors. Means were separated using Fishers protected LSD.

Results and Discussion

Seasonal conditions

In 2014 and 2015, there was rainfall >20 mm in the week prior to TOS 1. However, in 2016 the crop was sown into marginal moisture. In all three years >10 mm of rainfall occurred in the week prior to TOS 2. Growing season rainfall was about average in 2014 with lower than average spring rainfall. Growing season rainfall was slightly below average in 2015 with much lower than average spring rainfall and unseasonably warm spring weather resulting in a hot dry finish. Growing season rainfall in 2016 was above average with cool conditions and above average rainfall in spring.

Table 2. Yield and quality parameters of wheat from two times of sowing at Hart from 2014 to 2016. There was no significant difference of herbicide treatments on yield or yield components in this trial.

Year	Time of sowing	Yield (t ha^{-1})	Test weight (kg hL^{-1})	Screenings (%)	Protein (%)
2014	1	4.1	81.6	3.0	10.2
	2	2.9	81.5	3.0	11.4
	LSD (P=0.05)	0.4	ns	ns	0.9
2015	1	2.2	81.1	1.7	9.4
	2	1.5	78.5	12.1	12.3
	LSD (P=0.05)	0.1	0.8	1.4	0.8
2016	1	3.6	79.2	0.8	8.7
	2	4.9	81.5	0.8	7.1
	LSD (P=0.05)	0.2	0.4	ns	0.1

Grain yield and quality parameters
There was a significant effect of time of sowing on grain yield in each year of the trial (Table 2). Wheat grain yield was higher for the early time of sowing in the two seasons (2014 and 2015) characterised by dry and warm finishes. In 2016 however, the effect of time of sowing favoured the later sown crop given the cooler and wet conditions during grain fill. Protein was also significantly different between times of sowing in every year with higher protein in the lower yielding treatments, which can be attributed to yield dilution effects. Test weight was significantly different between times of sowing in 2015 and 2016. In 2015, test weight was higher at TOS 1, but in 2016 test weight was higher at TOS 2. Screenings were only significant between times of sowing in 2015, when the early hot and dry finish led to high screenings for TOS 2. Pre-emergent herbicide treatments did not influence final grain yield or quality.

Weed seed production is a crucial measure for integrated weed management. Seeds produced at the end of the season top up the weed seed bank for future years (Kleemann et al. 2016). We estimated seed number by counting seed heads at harvest. In every year, there was a significant TOS by herbicide treatment interaction for annual ryegrass seed heads (Table 4). In 2014, but not 2015 and 2016, there was a significant difference in annual ryegrass seed heads in the nil herbicide treatment with time of sowing. Where herbicides were applied, there was no significant difference in annual ryegrass seed heads between times of sowing, except for 2015, where there was more seed heads at TOS 2 in the trifluralin plus triallate treatment (treatment 5).

Annual ryegrass control and seed head production
Across the three years all pre-emergent herbicides provided similar control of annual ryegrass, regardless of sowing date (Table 3). Early ryegrass counts showed all pre-emergent herbicides reduced annual ryegrass numbers compared to the control. Sowing time had little or no effect on the performance of pre-emergent herbicides against ryegrass except in 2016. In 2016, there were significantly fewer annual ryegrass plants in crop at TOS 2 for the nil herbicide treatment compared to TOS 1. However, when the herbicides were applied, there was no difference in annual ryegrass numbers between the two times of sowing.

Table 3. Effect of time of sowing and pre-emergent herbicides on annual ryegrass density in crop at Hart between 2014 and 2016.

Herbicide treatment	Annual ryegrass plants in crop (plants m^{-2})					
	2014		2015		2016	
	TOS 1	TOS 2	TOS 1	TOS 2	TOS 1	TOS 2
1	59	77	18	6	42	13
2	21	12	3	1	17	33
3	8	8	1	2	12	13
4	6	12	2	2	25	15
5	3	3	0	1	22	8
6	8	6	1	2	17	14
Mean	17	20	4	2	23	16
LSD (P=0.05)						
TOS x herbicide treatment	ns		ns		19	
Herbicide treatment	11		5		-	

The lack of difference in annual ryegrass populations with delayed sowing in these trials indicates that annual ryegrass in continuously cropped systems has changed its behaviour to synchronise with sowing time. Chauhan et al. (2006) showed that no-till systems resulted in later annual ryegrass emergence compared to tilled systems. Control of early emerging weeds with knockdown herbicides may have selected for greater dormancy in annual ryegrass, such has occurred in other grass weeds that require darkness and/or chilling to germinate (Kleemann and Gill 2006; 2013; Fleet and Gill 2012). This will result in more annual ryegrass germinating after the crop has been sown. Therefore, there is little advantage in delaying sowing in order to control more weeds prior to sowing.

Conclusion
Despite very different seasonal conditions across 2014 to 2016, there was no disadvantage in annual ryegrass control due to early sowing of wheat. Therefore, in continuously cropped systems, there may be little advantage in delaying sowing in order to control more annual ryegrass. Early sowing with effective pre-

emergent herbicides provided effective control of annual ryegrass and limited annual ryegrass seed production to no more than observed with later sowing in all three years. In 2 out of the 3 years, early sowing also resulted in higher wheat yields. The advantages of early sowing may not be evident in longer seasons where the later sown crops can take more advantage of favourable spring grain filling conditions. In other situations, early sowing with effective pre-emergent herbicides may increase yield without compromising annual ryegrass control.

Table 4. Effect of time of sowing and pre-emergent herbicides on annual ryegrass seed heads at harvest at Hart between 2014 and 2016.

Herbicide treatment	Annual ryegrass seed heads (spikes m^{-2})					
	2014		2015		2016	
	TOS 1	TOS 2	TOS 1	TOS 2	TOS 1	TOS 2
1	350	164	45	44	116	99
2	74	35	5	9	43	37
3	39	41	3	13	12	15
4	20	36	6	14	41	52
5	32	9	0	15	37	35
6	71	14	8	9	45	35
Mean	98	50	11	17	49	46
LSD (P=0.05)						
TOS X herbicide treatment	89		12		21	

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