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## **NEXT MEETING**

**Wednesday the 18th of September at the Spalding Hall from 7.30pm**

**This meeting held in collaboration with the Upper North Farming Systems group**

**Pat Guerin - Balco Australia.** Getting quality hay and meeting market requirements for chemical residues in hay and straw

**Mick Faulkner - Agrilink Consulting.** The new MESONET weather station network. A look at its use for the planning of spraying, harvesting and burning operations

**Leighton Wilksch - Agbyte Agriculture Sensor Technology.** Of recent ABC radio fame, Leighton will give an update of new telemetry technology, updated weather forecast modelling, soil moisture probes and weather stations

**This meeting will be webcast to ensure wide access to members.**

**Zoom meeting details;  
<https://zoom.us/j/364539058>  
meeting ID: 364 539 058**

**\*\*\*\*\*SAVE THE DATE\*\*\*\*\***

**9th October, 1.30 pm. Roseworthy trials work and  
BBQ dinner - details to come**

### **GST on Subscriptions.....**

The Crop Science Society (SA) Inc. has deregistered for the purposes of GST, and as such the subscriptions for 2019-20 will be \$30 only. Any overpayments can be carried forward to future subs, or reimbursed if requested. President, Craig Davis.

Observations this month from our President....

Frost and spring dry conditions are turning grain crops into opportunistic hay crops (Craig Davis)



# Herbicide residues from summer spraying: Are they an issue for crop growth?

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## Abstract

Despite the acknowledged benefit of summer spraying of weeds to conserve soil moisture, the subsequent presence of herbicide residues has led to growers and advisors questioning whether these residues may be affecting biomass and early vigour of the following crop. This is particularly of concern in low rainfall regions with sandy soils where rainfall is sporadic and microbial activity low. Through a combination of field and glasshouse experiments across the Mallee region of South Australia and Victoria, we investigated the impact of summer spraying of glyphosate, 2,4-D amine or a mixture of both on early biomass, vigour and yield of four crop species wheat, barley, lentils, and lupins. The herbicide applied over the summer period established high concentrations of the active ingredient in soil when measured prior to sowing. The herbicide residues did not negatively affect the early biomass, vigour, or yield of cereal crops wheat or barley at any of the three 2018 field sites despite the autumn period being among the driest on record. Only negative biomass and yield responses were measured for 2,4-D herbicide treatments when label plant back recommendations were not adhered to with the lightest textured soil more prone to crop damage. These results suggest that current summer spraying practices of glyphosate and 2,4-D amine as recommended by label rates are unlikely to cause any significant crop damage in wheat, barley, lentils and lupins.

## Key Words

glyphosate, 2,4-D amine, low rainfall, sandy soils

## Introduction

In low rainfall farming systems, there has been an increase in the frequency and diversity of herbicide usage following the adoption of summer spraying to keep paddocks free of weeds and preserve soil water. Farmers and advisors are beginning to raise production issues relating to emergence and establishment of some crops, which they are attributing to herbicide residues. There is increasing anecdotal speculation that routinely sprayed summer herbicides such as 2,4-D and glyphosate are causing soil health issues and negative impacts on the growth and establishment of the subsequent crop. Furthermore, the management of residues in the low rainfall areas is difficult because most plant back interval and residue management guidelines were developed based on studies in medium to high rainfall areas and on medium to heavy texture soils rather than the sandy soils that dominate some of the low rainfall areas. Previous work in this area (Macdonald et al. 2017; Rose et al. 2018, Van Zwieten 2016) has shown that most cropping soils have herbicide residues accumulating with glyphosate, its primary metabolite AMPA and 2,4-D among those herbicides detected most frequently. While the herbicides can be detected in the soil, there has been less work showing the link between residue concentrations and their effect on early vigour, biomass and yield. The aim of this work was to evaluate whether levels of glyphosate and 2,4-D amine residues in the soil measured at sowing affects early biomass, vigour and yield of the subsequent crop grown.

## Methods

Field trials were conducted at three locations in the South Australian and Victorian Mallee: Cooke Plains (35°21'47.2"S, 139°38'44.5"E), Lameroo (35°14'46.7"S, 140°23'47.0"E), and Mittyack (35°09'35.3"S, 142°30'17.6"E) targeting low rainfall environments. Soils at each location were light textured sandy soils with low organic carbon (0.35-1.1%) and pH ranging from 6.3 to 7.1 (1:5 water). At each location, the trial treatments were structured to generate different levels of herbicide residues in the soils by applying a high rate (the equivalent of spraying summer weeds four times at label rates) in either summer (16<sup>th</sup> February 2018 at Cooke Plains, 12<sup>th</sup> February 2018 at Lameroo and 2<sup>nd</sup> February 2018 at Mittyack) or the day before sowing. These rates were deliberately applied for research purposes to create high concentrations in the soil and are considered outside of best economically viable practice. The herbicide treatments were unsprayed, Glyphosate 450 CT, 2,4-D amine 475 and a mixture of both herbicides. This approach had the added benefit of two unsprayed controls; one from the summer spray timing and another from the pre-sowing spray timing.

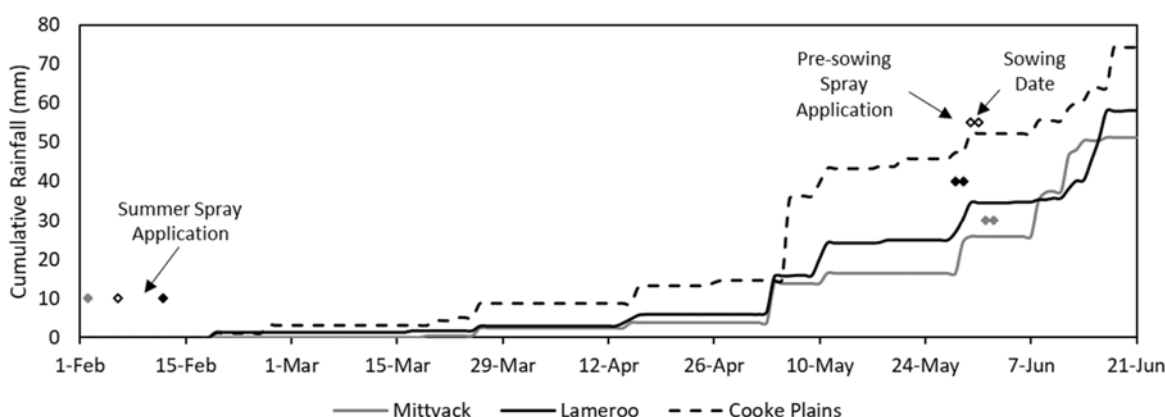


Field trials were set up as a randomised complete block design with 4 crops, 8 herbicide treatments and 3 replicates. The crops were lupins *cv. Mandelup*, lentils *cv. Jumbo 2*, wheat *cv. Scepter* and barley *cv. Spartacus CL*. Plots were sown as 6 rows by 22.86cm spacing (1.37 metres wide) and 5 metres in length. Cooke Plains was sown on the 31<sup>st</sup> of May, Lameroo on the 29<sup>th</sup> of May, and Mittyack on the 3<sup>rd</sup> of June. Plots were monitored for weeds, pests and disease and sprayed as necessary. Measurements on each plot consisted of plant counts for establishment, NDVI and biomass cuts at GS30 or 6-8 weeks post sowing to assess early growth and vigour, and harvest yield. For each of the unsprayed and sprayed (mixture herbicide) plots that were sown to wheat, 4 soil cores (13mm diameter) of the top 10cm were collected and bulked the day before sowing. These samples were analysed for glyphosate, AMPA its primary metabolite and 2,4-D amine residues by CSIRO using standard analytical methods. Differences between treatments were analysed using analysis of variance (ANOVA) and multiple comparisons using Tukey's test ( $p \leq 0.05$ ) with Genstat V19.1 Statistical Package.

## Results

### Environment information

Rainfall prior to sowing was low for all sites with the majority falling in May (Figure 1). Annual rainfall for each site in 2018 was between the 5<sup>th</sup> and 10<sup>th</sup> percentile from long-term rainfall data: 261.2 (364.2) at Cooke Plains, 208.4 (308.9) at Lameroo and 139.1 (297.2) at Mittyack in mm for annual and long-term median rainfall (in brackets) respectively.



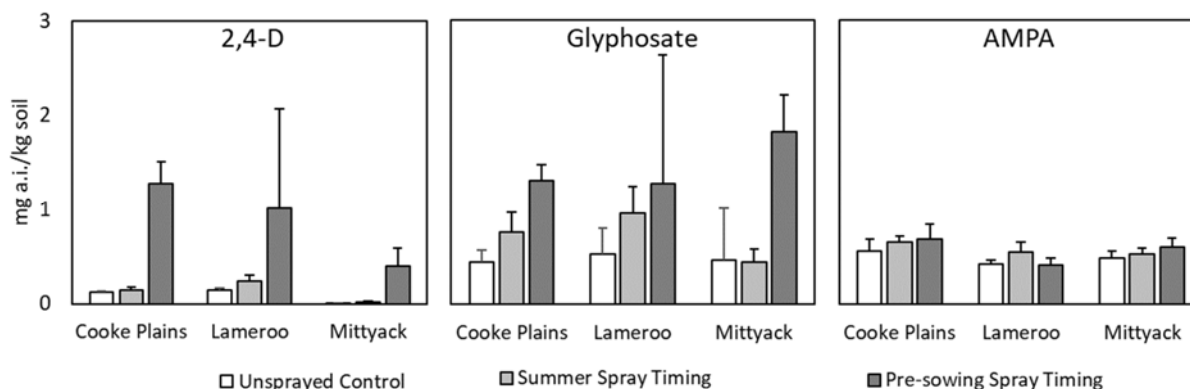
**Figure 1: Cumulative rainfall for all three field sites from the summer spray application to post crop sowing date. The timing of herbicide application and sowing date are shown on graph. Rainfall data was taken from the nearest Bureau of Meteorology (BOM) Station with a complete data set for 2018 (Mittyack BOM station 76069, Lameroo BOM Station 25562, Cooke Plains BOM station 25502).**

### Herbicide residues

Each site had a different starting herbicide residue profile but all soils contained some background level of glyphosate, AMPA and 2,4-D (Figure 2). Glyphosate levels in control plots were on par with the average load measured in SA soils by Van Zwieten et al (2016) although 2,4-D residues were higher and more on par with NSW-Qld soils and AMPA levels less than the average load suggesting less breakdown in the soils in our study. A single application of 2L/ha of glyphosate 450 would result in 0.57 mg of active ingredient (a.i.)/kg of soil whereas a single application of 1.8L/ha of 2,4-D amine 475 would result in 0.54 mg a.i./kg of soil assuming a soil bulk density of 1.6 g/cm<sup>3</sup> and. All sites had glyphosate levels equivalent to a single application of glyphosate in the control plots but had starting 2,4-D levels well below a single application.

Glyphosate residues were present in all plots with highest levels for those applied just prior to sowing and summer application rates not completely degrading back to unsprayed control levels by the time of residue testing. Importantly the glyphosate residues from the pre-sowing spray timing for all 3 sites were above the critical threshold of 1.2 mg/kg observed by Rose et al (2017) to cause biomass reduction of lupins in the presence of phosphorus fertiliser. The AMPA residues remained constant and did not seem to accumulate during the time from application to sowing suggesting minimal breakdown of glyphosate to AMPA in these soils.

Soil analysis determined that 2,4-D was present at higher concentrations only when it was applied the day prior to sowing whilst the summer application in all soils had degraded back to similar levels as the unsprayed control. Despite one of the hottest and driest autumns on record, this finding is consistent with label plant back recommendations which are defined by time and rainfall, in the case of 2,4-D, 15mm of rain must fall prior to the commencement of the plant back period; 3 days for barley, 7 for wheat, 10 for lentils and 21 for lupins.)



**Figure 2: Herbicide residue concentrations detected at sowing in soil samples taken from the top 10cm of wheat control and herbicide mixture treated plots. Concentrations reported as mg of active ingredient per kg of soil.**

#### Plant health responses

At both the South Australian sites, there were no differences in plant density, NDVI or early biomass between herbicide treatments. Only differences existed between crop types (data not shown).

At Mittyack, both the mix and the 2,4-D treatment that was applied the day before sowing reduced lentil establishment from 95 to 10 and 18 plants/m<sup>2</sup> respectively when compared to the control (ANOVA  $p \leq 0.05$  l.s.d. 16 plants/m<sup>2</sup>). In this case, crops were sown the day after herbicide application, well short of the plant back period for lentils of 10 days after 15mm of rainfall and is not recommended. This was the only interaction between crop type and herbicide treatment for any of the results across the three sites. At Mittyack a significant reduction in early vigour and biomass was also measured by NDVI 6.5 weeks after sowing and by a dry matter cut at GS30 (Table 1) in response to the 2,4-D amine application that occurred within a day of sowing and did not adhere to plant back periods for any of the crops.

**Table 1: NDVI and Biomass for Mittyack site**

	NDVI	Biomass (t/ha)
<b>Crop effect</b>		
Lentils	0.164	0.14 a
Lupins	0.164	0.20 a
Barley	0.181	0.55 c
Wheat	0.179	0.40 b
<i>l.s.d (p ≤ 0.05)</i>	<i>n.s</i>	<i>0.07</i>
<b>Herbicide Effect</b>		
Summer Control	0.185 b	0.37 bc
Pre-sowing Control	0.190 b	0.39 c
Summer 2,4-D	0.181 b	0.44 c
Pre-sowing 2,4-D	0.137 a	0.19 a
Summer Glyphosate	0.194 b	0.31 abc
Pre-sowing Glyphosate	0.183 b	0.35 abc
Summer Mix	0.173 b	0.32 abc
Pre-sowing Mix	0.134 a	0.23 ab
<i>l.s.d (p ≤ 0.05)</i>	<i>0.02</i>	<i>0.10</i>

\*Severely droughted no harvest

**Table 2: Yield (t/ha) for all three field sites**

	Lameroo	Cooke Plains	Mittyack
<b>Crop effect</b>			
Lentils	0.07 a	0.10 a	*
Lupins	0.13 a	0.12 a	0.11 a
Barley	1.54 b	2.42 c	0.41 c
Wheat	1.69 b	1.96 b	0.29 b
<i>l.s.d (p ≤ 0.05)</i>	<i>0.26</i>	<i>0.17</i>	<i>0.06</i>
<b>Herbicide Effect</b>			
Summer Control	1.09	1.32	0.35 c
Pre-sowing Control	0.74	1.08	0.32 c
Summer 2,4-D	0.79	1.18	0.31 bc
Pre-sowing 2,4-D	0.89	0.96	0.17 ab
Summer Glyphosate	0.73	1.26	0.29 abc
Pre-sowing Glyphosate	1.07	1.15	0.31 bc
Summer Mix	0.83	1.15	0.25 abc
Pre-sowing Mix	0.73	1.10	0.15 a
<i>l.s.d (p ≤ 0.05)</i>	<i>n.s.</i>	<i>n.s.</i>	<i>0.09</i>

For both South Australian sites Lameroo and Cooke Plains, the only yield differences detected were for crop type (Table 2). Both lentils and lupins had very low yields at both these sites of less than 0.2 t/ha<sup>1</sup> and struggled in the 2018 drought. Cereal yields at both Lameroo and Cooke Plains were higher than Mittyack.

However, there were no differences due to the herbicide treatments despite higher 2,4-D levels being measured in soil samples at both sites than measured for the Mittyack soil.

The very dry season at Mittyack resulted in low yields for all crops with the lentil plots suffering crop death and complete crop failure. The early biomass and NDVI effects reported earlier from Mittyack translated to a significant yield penalty, suggesting biomass was important for yield at this site in 2018. Once again, the 2,4-D and the mixture treatment applied pre-sowing resulted in a reduced yield compared to the unsprayed controls.

Not many studies have determined critical thresholds for glyphosate and AMPA in sandy soils with only a few on selected crops. For lupins in the presence of P fertiliser it is 1.2 mg of glyphosate/kg of soil and for wheat 6.75 mg/kg (Rose et al 2017). We achieved soil concentrations higher than 1.2mg/kg in our study but did not record any biomass reductions in lupins due to glyphosate. To achieve the wheat critical threshold we would need to have sprayed equivalent to 12 applications at label rates with no herbicide losses or breakdown. However, in a Canadian study, for a 20% reduction in shoot biomass of wheat the critical thresholds were substantially higher at 120-320 mg of glyphosate/kg of soil and 80-120 mg of AMPA/kg of soil (Blackshaw and Harker 2016). The likelihood of achieving these concentrations under field conditions is extremely low.

### Conclusion

Given the 2018 season was one of the hottest and driest autumns on record we expected little breakdown of crop herbicide from summer spraying. While we observed higher concentrations of herbicides in the soil at sowing compared to unsprayed controls, we did not see any negative establishment, biomass or yield response from our summer spraying treatments at any of the sites.

Glyphosate and AMPA did not cause any significant negative plant health responses in any crop type, spraying time or location. The only negative responses were due to 2,4-D amine residues from spraying the day before sowing. This practice is not recommended and is outside of label plant back recommendations. Based on these findings it is likely that herbicide residues will be present in soils and may not completely breakdown within a season or prior to sowing. However, if herbicide labels are adhered to and plant back recommendations are followed, they are unlikely to cause a problem in most soils. Lighter textured soils, along with crops that have greater plant back recommendations such as legumes are likely to show the first signs of issues particularly in a dry season.

### Acknowledgements

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Special thanks to Robert Pocock, Kevin Roberts and Scott Anderson for allowing us to run our trials on their land at Lameroo, Cooke Plains and Mittyack.

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# Management of early sown wheat: Evaluation of G x E x M interactions to increase harvest index and yield of early sown wheat

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## Abstract

Early sown slow developing wheats offer increased biomass accumulation, grain number and thus potential grain yield. However, the greater vegetative growth of early sown crops can result in low harvest index (HI). We evaluated management strategies to improve HI in three early sown winter wheat cultivars using four experiments conducted across south eastern Australia. Strategies included low stand densities (30-50 plants/m<sup>2</sup>), defoliation, and deferred application of nitrogen fertiliser. We found low stand densities had a small positive effect on HI and grain yield. Defoliation tended to increase HI and but also reduce yield (depending on cultivar) due to reduced biomass which negated much of the increase in HI. Deferring nitrogen had a variable effect depending on starting soil N and timing of in-season rain to allow crop uptake of top-dressed N. The management factors studied here have some potential for improvement of HI but responses were variable and with small effect sizes. We conclude that genetic improvement is required to raise HI and yield in early sown wheat.

## Key Words

Winter wheat, grazing, seeding rate, nitrogen

## Introduction

Wheat production in Australia is dominated by fast-developing spring cultivars that when sown in late-autumn will flower at an optimal time in early-spring. Recent research has demonstrated that water limited potential yield can be increased by sowing winter or slow-developing spring wheats earlier than currently practised such that they flower at the optimal time but have a longer vegetative phase duration (Hunt *et al.* 2019). Sowing earlier with slow developing cultivars can increase biomass accumulation, grain number and thus potential yield. However, results from studies in SE Australia have demonstrated that long phase duration yields have been only equivalent to those of faster developing cultivars sown on time (Hunt *et al.* 2019, in these conference proceedings) from a similar flowering time. Gomez-Macpherson and Richards (1995) found in their experiments and in reviewed experiments of others (Batten and Khan 1987; Connor *et al.* 1992) that the grain yields of slow developing cultivars were equivalent to faster developing cultivars sown later due to low harvest index (HI) in early sown cultivars.

Harvest index (HI) is the ratio of grain to total shoot dry matter and can be used as a measure of reproductive efficiency. It is a trait determined by interactions between genotype (G), environment (E) and crop management (M). Historic yield gains due to breeding have largely been achieved by increasing HI implying strong genetic control. Environmental factors are likewise important, and include seasonal pattern of water supply (Passioura 1977; Fischer 1979) and extreme temperatures during crop reproductive development.

There are two likely explanations for reduced HI in early sown slow developing cultivars. A longer vegetative phase means that a greater proportion of water supply is used prior to anthesis in comparison to faster cultivars sown later. In glasshouse experiments, the ratio of pre- and post-anthesis water use has been demonstrated to be strongly related to HI (Passioura 1977). The second explanation is that increased plant height and more leaves lead to competition for carbohydrates between the developing spike and elongating stem of early sown crops (Gomez-Macpherson and Richards 1995). Agronomic management strategies such as plant stand density, timing of nitrogen application, and crop defoliation can be used to alter early dry matter accumulation, seasonal pattern of water-use and carbohydrate partitioning in order to improve HI. Here, we evaluate the effect of these strategies to improve HI and grain yield in early sown crops.

## Methods

Two field sites were chosen for evaluation of management strategies for early sown winter wheat representative of the major medium-low rainfall environments in which wheat is grown in SE Australia (Table

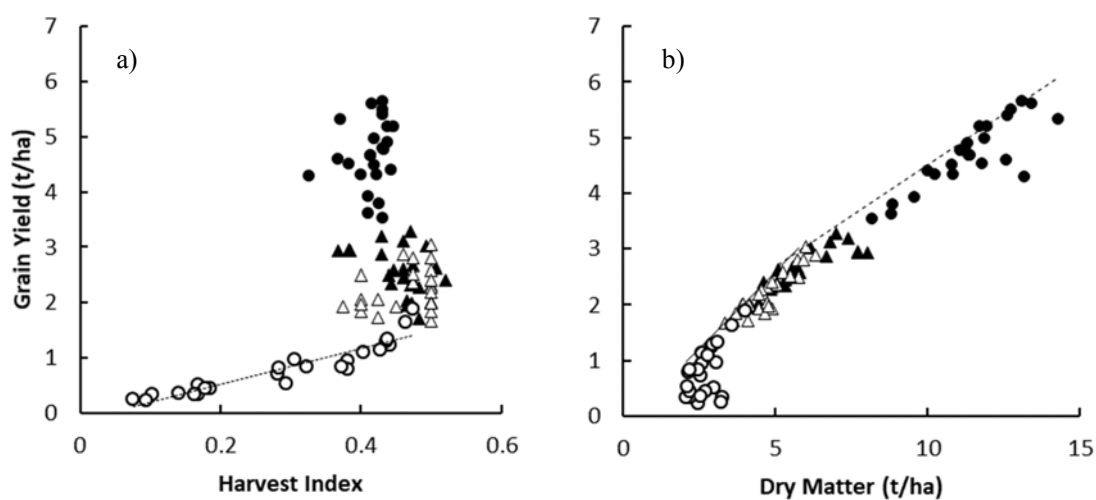
1), experiments were completed in both 2017 and 2018. At each site three winter cultivars Longsword (fast winter), Kittyhawk (mid winter), and DS Bennett (mid-slow winter) were planted in mid-April which is optimal for winter cultivars. Management factors applied included; 1) two nitrogen timings (seedbed N and deferred N) ensuring either adequate N supply at sowing or deferred until early stem elongation; 2) two defoliation treatments to simulate grazing (control and defoliation) applied by mechanical mower twice during tillering before Z30; 3) two plant stand density treatments (low and high) targeting 50 and 150 plants/m<sup>2</sup> respectively. Management factors were applied to each cultivar in a factorial fully randomised complete block experiment which equating to eight management combinations per cultivar per site with four replications. 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-lines placed in seeding furrows, to germinate seed and allow emergence. Harvest index (HI), dry matter (DM), and grain yield (GY) were measured from quadrat cuts (0.46 m<sup>2</sup>) taken at crop maturity and analysed individually using mixed linear models or across environments using ANOVA with site year, cultivar, nitrogen, defoliation, and plant density as factors/fixed effects and block structure as random effects.

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

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. Yarrawonga VIC	81124 (1994-2018)	469	140	276	161	135
2. Loxton SA	24013 (1896-2018)	261	120	135	83	92

## Results & discussion

There was significant variation in HI, DM, and GY across experiments. The largest effect size was generally due to environment (Table 1 and Figure 1a). Higher HI were achieved at Loxton compared to Yarrawonga in both seasons due to a greater severity of frost and sterility at Yarrawonga. There was a strong positive relationship HI and GY at Yarrawonga in 2018 ( $R^2=0.86$ ), likely due to the severe stem and flowering frost events that significantly impacted grain number and thus yield. At other sites under moderate temperature stress HI was not correlated with GY. This means a higher HI did not always result in higher grain yield. The strong relationship with DM and GY within treatments of similar harvest index at Yarrawonga in 2017 ( $R^2=0.71$ ), and Loxton 2017 and 2018 ( $R^2=0.79$ ) suggest that total biomass can be improved along with maintenance of a high harvest index using G x M strategies (figure 1b) to improve crop yield.



**Figure 1. Relationships between harvest index (a), dry matter (b) and grain yield at Yarrawonga 2017 (●), Yarrawonga 2018 (○), Loxton 2017 (▲), and Loxton 2018 (△).**



**Table 2. Analysis of variance output for significant management factors influencing HI, DM, and GY. (<0.001=\*\*\*, <0.01=\*\*, <0.05=\*)**

Management Factor#	HI	DM t/ha	GY t/ha
Environment	***	***	***
Cultivar	***	ns	**
Defoliation	***	***	**
N timing	***	ns	ns
Stand density	ns	***	***
Cultivar x environment	***	**	***
Environment x N timing	***	*	ns
Environment x stand density	**	***	***
Environment x cultivar x defoliation	***	**	*

#all other management factors and combinations were not significant

All management factors interacted with environment (Table 2). Outside of environment, cultivar, and defoliation there was little interaction between seed rate and nitrogen timing. Defoliation was the most reliable management strategy to increase HI but responses were still variable and depended on cultivar and environment. In 7 out of 12 cultivar x environment combinations, defoliation increased HI but this response translated to a yield increase in only Longsword (0.5 t/ha) and Kittyhawk (0.4 t/ha) at one site (Yarrawonga in 2018) due to a delay in crop development reducing stem frost damage. Yield remained similar to undefoliated controls at 5 out of 12 situations, and decreased yield in 5 situations. Decreased yield responses to defoliation were generally explained by a reduction in total crop biomass. Longsword was the most responsive cultivar to defoliation (increased HI at all sites) whereas DS Bennett was the least responsive (increased HI at Yarrawonga in 2018 only).

Genotypic differences in HI were stable and consistent across sites. DS Bennett tended to have higher HI than both Kittyhawk and Longsword. However, this came with a trade-off in biomass and sometimes yield, and DS Bennett almost always had a lower biomass meaning yields between cultivars were often similar (Figure 1 and Table 3) at high and low HI. The improved biomass and grain number potential (data not presented) of cultivars like Longsword pave the way for genetic progress on improving traits strongly correlated to improved HI such as floret sterility, fruiting efficiency and biomass partitioning. When management strategies such as simulated grazing (defoliation) were effective in increasing HI this came at a trade-off in crop biomass similar to the responses observed between DS Bennett and Longsword.

**Table 3. Mean harvest index (HI), dry matter (t/ha), and grain yield (t/ha) of winter cultivars and the management effect size when defoliated. Different letters within a site indicate significant differences and ns indicates no significant effect of management.**

indicates no significant effect of management.							
Environment	Genotype	Control trait means			Management Effect (defoliation)		
		HI	DM (t/ha)	GY (t/ha)	HI	DM (t/ha)	GY (t/ha)
<i>Loxton 2017</i>							
	DS Bennett	0.46a	5.8b	2.7b	ns	-1.0	-0.4
	Kittyhawk	0.43b	6.9a	3.0a	+0.07	-2.5	-0.8
	Longsword	0.41c	7.0a	2.8a	+0.12	-1.8	ns
<i>Loxton 2018</i>							
	DS Bennett	0.50a	4.4b	2.2b	ns	ns	ns
	Kittyhawk	0.42c	4.5b	1.9c	-0.02	ns	ns
	Longsword	0.47b	5.7a	2.6a	+0.03	ns	ns
<i>Yarrawonga 2017</i>							
	DS Bennett	0.42a	12.0b	5.1a	ns	-0.7	-0.3
	Kittyhawk	0.41a	12.2b	5.1a	ns	-2.1	-0.8
	Longsword	0.36b	13.0a	4.7b	+0.07	-3.3	-0.5
<i>Yarrawonga 2018</i>							
	DS Bennett	0.38a	3.3a	1.3a	+0.04	ns	ns
	Kittyhawk	0.11c	3.0a	0.3b	+0.18	ns	+0.4
	Longsword	0.17b	2.4b	0.4b	+0.20	ns	+0.5

### The effect of stand density and nitrogen timing on HI depended on environment (

Table 4). Plant density was generally an ineffective strategy with a significant effect on HI at only 1 out of the 4 site years. HI was improved by 0.03 with a lower stand density at Loxton in 2017 which translated to a small increase in GY of 0.3 t/ha. At Yarrawonga in 2017, the yield response to lower densities was due to increased DM of 1.4 t/ha and not HI. These results are significant for management as it suggests targeting 50 plants/m<sup>2</sup> is sufficient to allow maximum yields to be achieved but is not a reliable strategy to increase HI.

**Deferring N until stem elongation increased HI by 0.04 at Loxton in 2017 and by 0.01 at Yarrawonga in 2017 and 0.07 in 2018, however this came with a trade-off in biomass at Loxton resulting in a small yield penalty (**Table 4). At Yarrawonga a small improvement in HI did not improve yield in 2017 but a 0.07 increase in HI in 2018 resulted in a 0.3 t/ha yield increase. Except for Yarrawonga in 2017, lack of spring rainfall may have reduced the crop's ability to take up top-dressed N.

**Table 4. Management effect of deferring N until Z30 and lower plant density on mean harvest index (HI), dry matter (t/ha), and grain yield (t/ha) across all winter cultivars. ns indicates no significant effect of management.**

	Effect of deferring N until Z30			Effect of lower plant density		
	HI	DM (t/ha)	GY (t/ha)	HI	DM (t/ha)	GY (t/ha)
Loxton 2017	+0.04	-0.7	-0.1	+0.03	ns	+0.3
Loxton 2018	ns	ns	ns	ns	ns	ns
Yarrawonga 2017	+0.01	ns	ns	ns	+1.4	+0.8
Yarrawonga 2018	+0.07	ns	+0.3	ns	ns	ns

### Conclusion

The management factors presented here have shown limited scope to improve HI and yield in early sown crops. Defoliation had the most reliable effect on HI but also tended to reduce biomass which negated much of the increase in HI. Responses to stand density and nitrogen timing were variable and with small effect sizes. Given the limited effect of management strategies found here, we propose that genetic improvement is the most promising avenue for increasing HI and yield in early sown wheat, and postulate that this could be achieved more rapidly through early generation screening for partitioning traits such as HI and fruiting efficiency in slow developing genotypes.

### Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC through research project number GRDC9175069. The authors would like to thank them for their continued support.

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# GM CROPS

## GROWER FACT SHEET

GPSA has consistently argued that the moratorium offers little in the way of trade and marketing benefits to the majority of agricultural producers in SA and only removes the option of using GM tools which have been independently proven to be safe and effective.

GPSA believes that growers deserve the freedom to grow the cereal, legume and oilseed varieties that best fit their farming system.

### The regulatory framework

Under the *Genetically Modified Crops Management Act 2004*, the area designated in which no GM crops can be grown is set out in the *Genetically Modified Crops Management Regulations 2008*.

Any changes to the area designated under the regulations attracts a statutory six-week consultation process.

### The Independent Review

The Government's decision comes after an independent review by Professor Kym Anderson found that the moratorium has cost SA's grain industry at least \$33 million since 2004. In addition to the \$33 million cost, Professor Anderson's review has found that:

- there is no price premium for grain from South Australia despite it being the only mainland state with a GM crop moratorium,
- the moratorium will continue to hurt South Australian producers with (at least) another \$5 million cost if the moratorium continues until 2025,
- GM crops typically use less, rather than more farm chemicals when compared to conventional crops,
- GM crops can also deliver reduced weed control costs and increased yields,
- KI growers would be able to preserve their unique non-GM market,
- South Australia's moratorium has discouraged both public and private research and development investment in this state,
- removing the moratorium will attract or retain research dollars, scientists, and post-graduate students in South Australia, and
- segregation protocols (such as those used interstate) ensures the successful co-existence of GM and non-GM crops.

Following the release of the review, GPSA identified the need for targeted consultation with growers on Kangaroo Island in relation to findings 2.2 and 4.4 respectively.

### Kangaroo Island growers

GPSA held a public forum for primary producers on 15 March 2019 in Parndana to discuss the findings from the Independent Review.

The consensus at the Forum was that section 4 of the *Genetically Modified Crops Management Regulations 2008* ought to be amended to limit the moratorium to Kangaroo Island only (as shown):

#### 4—Designation of area in which cultivation of genetically modified food crops is prohibited

Pursuant to section 5(1)(a)(ii) of the Act, *the whole of the State Kangaroo Island* is designated as an area in which no genetically modified food crops may be cultivated.

On 19 March 2019 GPSA wrote to the Hon Tim Whetstone MP, the Minister for Primary Industries and Regional Development outlining this recommendation.







## Government announcement

On 19 August 2019, Minister Whetstone announced that the Government would restrict the moratorium to Kangaroo Island, triggering a six-week consultation process. This announcement mirrors GPSA's policy proposal to accommodate the geographically and economically unique circumstances of Kangaroo Island growers.

## Next steps

In accordance with the *Genetically Modified Crops Management Act 2004* formal written submissions will be accepted by PIRSA, and public meetings will be held in Adelaide and Kangaroo Island.

The statutory consultation commenced on 19 August 2019, with submissions to inform the new regulations accepted until 5pm, 30 September 2019.

Following statutory consultation, amendments to the regulations will be recommended to the Governor of South Australia taking into account feedback received. It is proposed that changes to the regulations will be operational on 1 December 2019 to enable producers to make decisions about their crops in 2020.

Any changes to the regulations is subject to a disallowance motion of either house of Parliament. More information on the consultation process, including the draft regulations, is available on the PIRSA website: [www.tinyurl.com/PIRSAGMconsult](http://www.tinyurl.com/PIRSAGMconsult)

## What this means for growers

If the Regulations are upheld, growers on mainland South Australia will have the freedom to grow the cereal, legume and oilseed varieties that best fit their farming system from 1 December 2019.

The moratorium will continue to apply to growers on Kangaroo Island until 1 September 2025.

## Parliamentary Inquiry

The Parliamentary Select Committee on the Cultivation of Genetically Modified Crops in South Australia is currently considering its draft report after over a year of operation. This inquiry is



separate and independent of the Government's own process.

This timing of the Government's announcement is critical to ensuring that mainland producers are in a position to choose suitable GM varieties that fit their farming system for the 2020 season

GPSA has been fully engaged with the Select Committee, including by making a submission and giving evidence at a public hearing.

## Lifting the moratorium on Kangaroo Island before 1 September 2025

GPSA understands that the Government will be able to lift the moratorium on Kangaroo Island before its expiry in 2025 by changing the Regulations, in a similar way to what is currently proposed.

GPSA has recommended that further consultation with local primary producers occur well in advance of the expiry of the moratorium, and in the event new GM varieties approved by the OGTR become available. This prohibition should not remain indefinitely and instead be subject to regular review.

Any future changes will attract the same mandatory six-week consultation period, and are subject to a disallowance motion of either house of Parliament.

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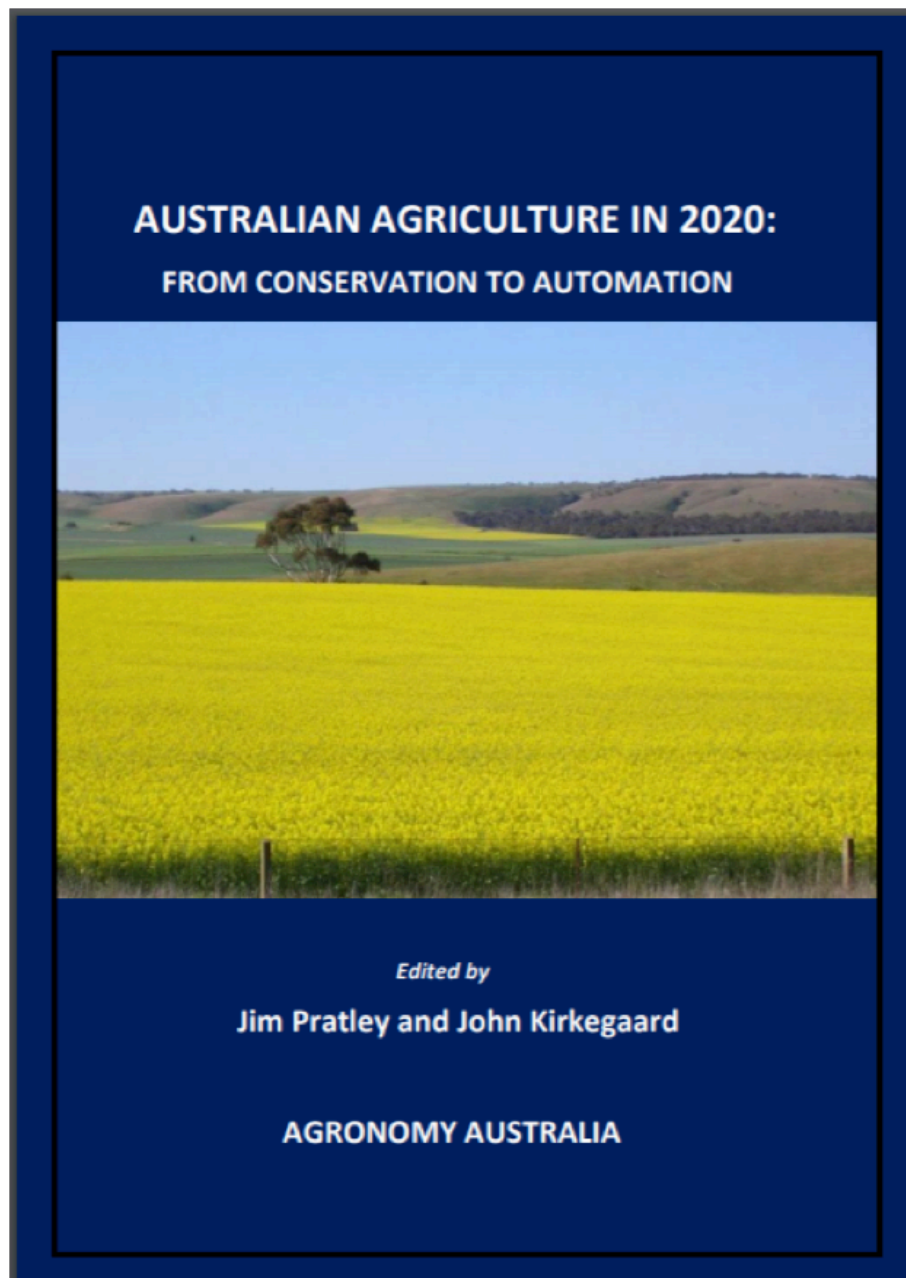
Fact sheet current as at 20 August 2019



## **Australian Agriculture in 2020: From conservation to automation**

Edited by Professor Jim Pratley and Dr John Kirkegaard and Launched at the 2019 Australian Agronomy Conference, Wagga Wagga NSW. This publication is essential reading for anyone with an interest in agronomy.

<http://www.agronomyaustraliaproceedings.org/images/sampled/data/specialpublications/AustralianAgriculturein2020.pdf>



## PREFACE

In the 1960s and 1970s there was much concern in the Australian community about the extent of soil degradation and erosion taking place on Australian farms from over-cultivation. At that time, reduced tillage, direct drilling and early attempts at 'chemical farming' were taking place. Initially the availability of Spray.Seed® was enabling reduced tillage and direct drilling to be trialled as a way of reducing the need to create a cultivated seedbed. The subsequent availability of glyphosate and the option of selective weed control using new chemicals such as diclofop methyl (Hoegrass®) facilitated the evolution of conservation farming, later to be incorporated in the broader international concept of conservation agriculture.

In 1980 the Australian Society of Agronomy, now Agronomy Australia, was formed following the first agronomy conference held at Gatton Campus, now University of Queensland. Subsequent conferences have been held approximately every two years. The 4th Conference was held in Hobart and the idea of a monograph that brought together the research on the tillage 'revolution' was conceived.

In 1987 Peter Cornish and Jim Pratley were asked by the Australian Society of Agronomy to produce a monograph on the 'new agronomy' particularly about minimum tillage and its components. That monograph, *"Tillage – new Directions in Australian Agriculture"*, was an integrator of the science and technology of the time and is still relevant 30 years later. Since that publication, however, there has been a quiet revolution which has transformed the landscape to one of soil stability from the degraded soils it replaced. But this new paradigm has not been without its own challenges, and this publication provides an integrated account of the evolution of the farming systems in the last 30 years, the new agronomy of today, and the challenges beyond 2020.

The 19th Agronomy Conference in 2019 at Wagga Wagga NSW, provides the opportunity to showcase the agronomy achievements over the last thirty years, and this monograph *"Australian Agriculture in 2020: from Conservation to Automation"* records those achievements and acknowledges the research teams and farmers who have been at the heart of agronomic progress.

We, the editors, wish to thank the more than 80 contributors without whose cooperation this publication could not have happened. A special thanks goes to John Broster and Julianne Lilley for their assistance in the final stages of preparation for publication.

We also wish to express our gratitude to Agronomy Australia for funding the project which facilitates access to the works so that Australian agronomy achievements can be widely recognised and celebrated. Finally, we acknowledge Charles Sturt University for undertaking the printing and electronic preparation needed to produce both formats of the book.

We commend the contents and the story to educators and future agronomists as the first-hand version of Australian agronomy. To other researchers it is a comprehensive account, fully referenced, to assist them to capture new opportunities for agriculture in the future, and to meet its ongoing challenges.

Thank you again to all who were involved in this journey.



**Jim Pratley**  
Charles Sturt University



**John Kirkegaard**  
CSIRO

# Competitive wheats: does more vigour early matter?

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## Abstract

Weeds are an ongoing challenge and herbicide-resistant weeds are on the rise. Incorporating weed-competitive varieties in the non-herbicide integrated weed management toolbox, make up a low cost and low risk approach to decrease the \$4.3 billion weed costs Australian growers every year. We have assessed the competitive ability of a diverse set of 100 entries. The 100 entries vary from historic and modern wheat varieties to wheat lines developed to have wide leaves and greater biomass at stem elongation. Among the entries were also durum wheat, triticale and barley. The 100 entries were grown under field conditions in seven environments over three seasons with and without competition from oat or barley used as a weed-surrogate. Through in season measurements and separation of wheat grains and weed-surrogate grains after harvest we identified that wheats with wide leaves and greater biomass at early stem elongation only experienced yield decreases of 4-10% when grown in competition with weed-surrogate, whereas the best varieties decreased yield by 14% and worst decreased yield by 35%. Weed suppression was greatest in the high vigour lines.

## Key Words

Weed-competition, vigour, diverse wheats, pre-breeding,

## Introduction

Weeds cost Australian growers an estimated \$4.3 billion annually (McLeod 2018). A rising cost is herbicides due to their decreasing efficiency following development of herbicide-resistant weeds. Non-herbicide integrated weed management (IWM) tools are in high demand to maintain the longevity of new and existing chemistries and reduce the cost of herbicide management increasing grower profitability. One such tool is crop competitiveness.

In natural plant communities, early vigour, defined as more rapid leaf area development through wide leaves and greater biomass at stem elongation, is a common mechanism for plant-to-plant competition (Aerts 1999). Introducing early vigour into wheat varieties creates a weed-competitive crop. A weed competitive crop variety is a non-herbicide IWM control tool and is easily implemented with other approaches and moreover with low cost and low risk.

Many weed species belong to the Grass family (*Poaceae*), as does wheat, making control management of grass species challenging in wheat paddocks. Further, the presence of herbicide-resistant ryegrass makes wheat the weakest link in weed management emphasising the need for non-herbicide approaches such as crop competition.

Assessing competitive abilities in wheat is challenged by the nature of weeds. Weeds show opportunistic growth habit, germinate continuously over the season, are conservative with resources, vary in density, and produce numerous often small seeds. Studies have assessed competitive abilities by growing crops in a weedy paddock (e.g. Benaragama and Shirliffe 2013, Mwendwa et al 2018). However, the naturally occurring density of weeds is too random for reliable assessment of hundreds of wheat genotypes, and sowing a natural weed at known density risks adding to the weed seed bank. A weed-surrogate is more reliable, can be mixed in before sowing and germinate uniformly. For wheat the most common weeds are ryegrass, wild radish and black oat, and the surrogates used are commercial oat, barley, canola and ryegrass (Lemerle et al 2001, Zerner and Gill 2010). Choice of tall and/or short weed-surrogate varieties can also further mimic the diversity in natural occurring weeds. Limitations by crop weed-surrogates is their constrained growth habit, similar to that of wheat.

The early vigour trait can be measured in several ways including plant biomass cuts, traditional scoring of growth by eye, and all ground cover measurements e.g. NDVI and CANOPEO (Patrignani and Ochsner 2015). For all approaches the timing of measurement play important role as the genotype with rapid early growth is often the most competitive (Lemerle et al 2004, Vandeleur and Gill 2004).

Vigorous crop growth is not the goal in itself for multiple reasons e.g. potential increased lodging and poor water use efficiency. This is where timing and response to growing environment is of great importance in development of a successful weed-competitive variety. Optimally the crop show both the ability to suppress weeds and to maintain yield in the presence of weeds.

## **Methods**

### *Plant material*

Entries in the field trials covered wheat breeding lines and commercial wheat varieties and also durum wheat, barley and triticale. Historic wheat varieties included Federation, Bencubbin, Olympic and Drysdale, and the more recent varieties Scout, Magenta and Mace. Breeding lines included high early vigour lines developed at CSIRO using the recurrent selection derived 'C3' as vigour donor. 'C3' is the 3<sup>rd</sup> cycle selection from a recurrent selection program incorporating alleles from across 28 diverse wheat lines (Zhang et al., 2015; Rebetzke and Richards 1999). Lines were topcross-derived using either Annuello (W020213), Wyalkatchem (W280504, W320101), Westonia (W250310) or Yitpi (W370303, W390403, W470503). Trials had representation of 29-33% Australian commercial varieties each season. Seed for all entries were sourced from irrigated seed-increase grown the previous year.

### *Field trials*

Entries were sown with a cone-seeder in 6m long plots containing 10 rows with 18cm row spacing. Weed-surrogate oat or barley and wheat seed were mixed pre sowing and sown together. Sowing rate was 160 seed/m<sup>2</sup> (100kg/ha) for wheat and the weed-surrogate oat cv. Mikita or barley cv. Fathom at 100 seed/m<sup>2</sup>. Experiments were sown with and without irrigation at Condobolin Central West Farming Systems Experimental Station, Yanco DPI Experimental station with irrigation and without irrigation at the CSIRO Agricultural Experimental Station in Boorowa in 2015, 2017 and 2018. Spraying and fertilisation were applied as necessary. Experimental design was a row-column containing paired plots with two to three replicates.

In season measurements varied with each experiment considering the season and hands available. In season, establishment of wheat and oat or barley, early vigour, and mature oat frequency were visually scored. Cuts were taken at anthesis or maturity to determine the number of oat/barley and wheat tillers, and wheat harvest index with and without competition. Groundcover was measured as NDVI or from photos and wheat height measured at maturity. All experiments were harvested at maturity and samples mixed of wheat and oat or barley were separated using an indent cylinder with a 30° angle and four runs per plot. A total of 20% of samples were hand sorted to estimate the error used for corrections.

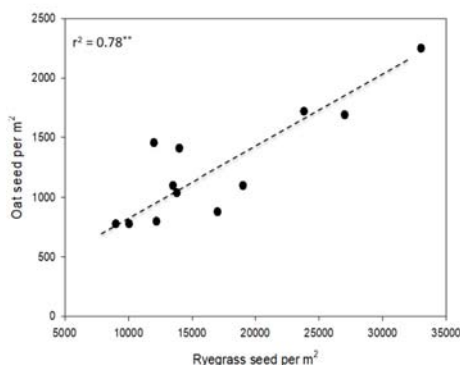
### *Data analysis*

Preliminary data analysis was performed using mixed models, REML in Genstat (VSN International 2017).

## **Results**

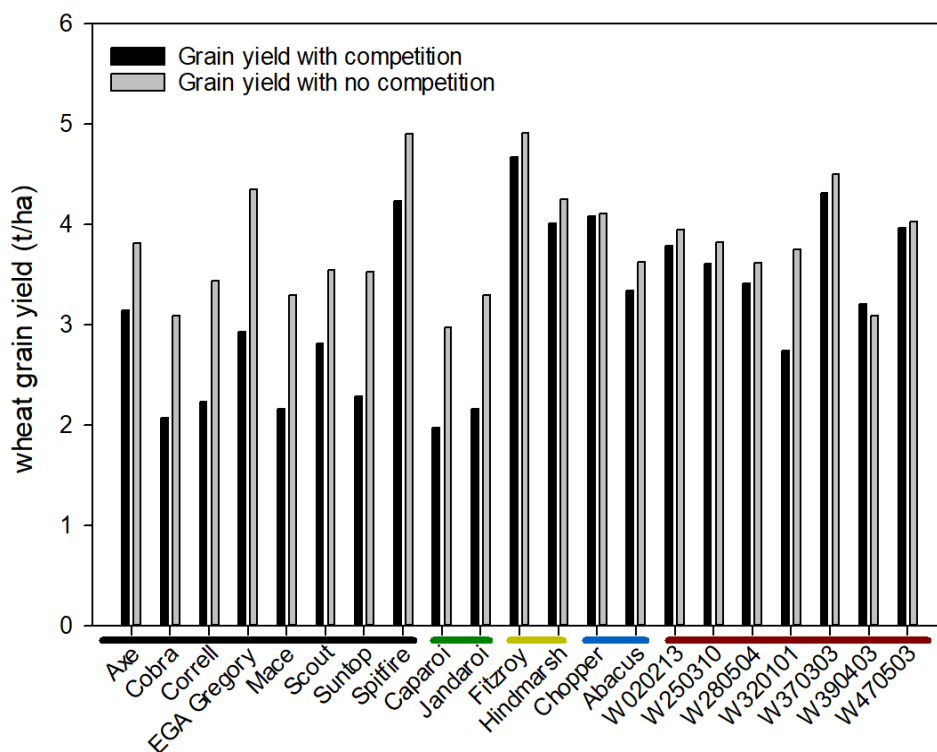
A previous study showed a strong positive correlation between commercial oat seed and ryegrass seed indicating commercial oat to be a reliable weed-surrogate (Figure 1). The commercial oat or barley established well throughout trials determined by cuts (data not shown), although in particular oat was difficult to visually distinguish from wheat at early growth stages.





**Figure 1. The association of biomass for ryegrass and weed-surrogate oat.**

Figure 2 shows wheat grain yield with and without competition of a representative selection of the included entries under irrigated conditions. The two durum wheats showed together with the commercial varieties Suntop, Mace and Corell the highest yield loss from competition (35%). The three commercial wheats Axe, Scout and Spitfire showed the strongest competition of all commercial varieties. All but one of the competitive lines (W320101) showed improved competition compared to the commercial varieties. Interestingly, the two competitive lines with the highest yield loss from competition of all competitive lines were both from the Wyalkatchem background. Triticale and barley, known to possess better competitive abilities than wheat, maintained greater grain yield under weed competition than all the commercial wheat varieties.



**Figure 2. Grain yield with and without competition (oat) of selected entries grown in Condobolin 2015 with irrigation. Entries underscored with the black line (–) are commercial wheat varieties, green are durum wheat, yellow are barley, blue are triticale and dark red are developed competitive lines.**

## Conclusion

Experimental competitive wheat lines showed improved weed-competitive abilities compared to commercial wheat varieties, maintaining yield when grown in competition with weed-surrogate. The results support the potential to breed for wheat-competitive varieties as a non-herbicide IWM tool.

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