23. Harvest Weed Seed Capture

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GRDC PROJECT SFS00032

KEY MESSAGES

- Timeliness of harvest is critical to try and maximise the number of annual ryegrass (ARG) weed seeds captured (prior to the onset of seed shedding)
- Harvest height will aid in the capture of increased numbers of ryegrass
- The amount of ARG captured will depend on conditions prior to harvest and the level of lodging that occurs prior to harvest
- When weed levels get too high, several years of alternative crop sequences may be required to get numbers down to an acceptable level

Background

The aim of this project was to see if harvest weed seed practices could be adopted to reduce annual ryegrass (ARG) weed seed populations to address herbicide resistance issues in high yielding, high rainfall zone (HRZ) areas of the southern region.

It is not fully understood how many weed seeds are being captured as part of the harvest process in the HRZ. It is thought that a percentage of weeds – particularly ARG may have shed prior to the harvest process, or alternatively may be lower than the harvest height. This project aims to investigate that issue further, quantify the amount of ARG seed being captured and look at the long term effects of Integrated Weed Management (IWM) techniques on the weed seed bank in the HRZ.

This project is a collaborative project being managed by Southern Farming Systems (SFS) with Mackillop Farm Management Group (MFMG) delivering on the South Australian component.

Activities

Small plot trials - Conmurra (2015-2017)

A long-term small plot trial was established at Conmurra in 2015. This was followed through to pre-seeding 2018 to look at the long term effects of the treatments. Treatments across all seasons are summarised in Table 1.

In 2015, 3 wheat varieties (Trojan, Manning and Beaufort) were sown into an area with high ARG populations (1300 pl/m^2) at three different times of sowing (each two weeks apart) and then harvested at two different heights (15cm and 30cm) to assess the impact of different management strategies on ARG weed control.

Wheat establishment, wheat head density at harvest, crop yield and grain quality were measured. Initial weed counts were taken, along with weed counts at 20days and 60 days post-sowing. Number of ARG weed seeds collected in the harvester were measured along with maturity.

In 2016 the crops were all sown down to Westminster barley at one time of sowing to assess the impacts of treatments imposed in 2015. Crop measurements were taken throughout the season as per 2015. ARG weed measurements were taken initially, 30 days and 60 days after sowing. The amount of seed shedded, ARG plants and seeds at harvest were also measured. Harvest heights were to be maintained, however with a decile 9 rainfall season, there were large implications on the management of the barley crop which lodged heavily (Figure 1) and as a result, harvest height treatments were unable to be imposed.

Figure 1: Lodging of crop at Conmurra

In 2017 due to extremely high ARG population levels (average of 727 pl/m^2) and the lack of ability to impact on ARG plant numbers significantly in previous seasons, the plots were sown down with either wheat (harvested for grain), wheaten hay (to simulate a failed crop due to high ryegrass numbers) or as a barley hay crop to see if ARG plant numbers could be reduced rapidly in one year.

Initial crop establishment counts were taken, and either crop grain yield or biomass quantity of hay cut measured. Initial ARG plant numbers, number of plants at 20 days and 60 days post-sowing, amount of seed shedded and plant numbers at harvest (either for hay or grain) were measured to determine effectiveness of the treatments.

Table 1: Conmurra trial treatments 2015-17

2015			2016		2017	
Variety	**TOS**	**Harvest Height**	**Crop**	**Harvest Height***	**Crop**	**Harvest Height***
Trojan Wheat	TOS1	15cm	Westminster Barley	10cm	Manning Wheat	15cm
		30cm		10cm		30cm
	TOS2	15cm		10cm	Manning Wheat (Hay)	-
		30cm		10cm		-
	TOS3	15cm		10cm	Westminster Barley (Hay)	-
		30cm		10cm		-
Manning Wheat	TOS1	15cm	Westminster Barley	10cm	Manning Wheat	15cm
		30cm		10cm		30cm
	TOS2	15cm		10cm	Manning Wheat (Hay)	-
		30cm		10cm		-
	TOS3	15cm		10cm	Westminster Barley (Hay)	-
		30cm		10cm		-
Beaufort Wheat	TOS1	15cm	Westminster Barley	10cm	Manning Wheat	15cm
		30cm		10cm		30cm
	TOS2	15cm		10cm	Manning Wheat (Hay)	-
		30cm		10cm		-
	TOS3	15cm		10cm	Westminster Barley (Hay)	-
		30cm		10cm		-

* Harvest Height impacted due to crop lodging

Large scale demonstration site - Furner 2015-16

A broadacre site was established prior to harvest in 2015 in Forrest wheat and harvesting occurred on 2nd January with a conventional harvester (12m swaths). The site was set up to compare the effects of the integrated Harrington Seed Destructor (iHSD) prototype with other IWM techniques including baling residues (done immediately post-harvest) and windrow burning and their effectiveness on weed control compared to harvesting high and burning on a paddock scale. Pre-harvest weed cuts were taken +/-30cms for the harvest high and burn treatment, and +/-15cms for all other treatments to gain an understanding of initial weed populations and also the effectiveness of the harvest process (ie. how much is captured by the harvester). Note that the site was grazed over summer.

In 2016, the site was sown down to broad beans and managed as per standard farmer practice. Weed measurements were taken across the plots, and in the windrow burn and windrow bale treatments, measurements were taken in the centre of the row and also off-centre. Pre-harvest measurements were again taken looking at the amount of ryegrass seed that was to be captured during the harvest process. The bean crop was harvested on 29th January 2017; a delayed harvest due to adverse harvest conditions. It was harvested at a height of approximately 12cms across the site. Figure 2 shows the bean crop pre-harvest.

Figure 2: Broad Bean crop immediately pre-harvest at Furner

Large scale demonstration – Wolseley 2017

A broadace harvest demonstration was conducted at Wolseley in 2017 in a wheat crop with harvest occurring on 28 December, 2017. The demonstration was both an opportunity for growers to view the iHSD in action (Figure 3) and for an assessment of the various harvest indices with two different harvesters to be made; one fitted with an iHSD for harvest weed seed control and one fitted with a narrow windrow chute. Both harvesters were NH Class 8 harvesters (CR8090) - the one with an iHSD was a 2017 model, and the harvester fitted with a narrow windrow chute was a 2016 model. The stubble surface post-harvest is shown in Figure 4.

Machine measurements were taken utilising the harvester monitors with a focus on fuel use, engine load and harvest efficiency. Weed measurements were also taken prior to harvest with the number of seeds above and below harvest heights measured to gain an understanding of the number of weed seeds being captured by the harvest process.

Figure 3: Field Day at Wolseley, 2017

Figure 4: Narrow windrows (centre) vs area harvested with iHSD and trash spread (RHS)

Results & Discussion

Small plot trials - Conmurra (2015-2017)

2015 (Y1)

Initial ARG weed populations (pre-knockdown) were measured at 1300 plants/m^2. The initial ARG seedbank populations (measured in blocks across the time of sowing plots) varied greatly from 650 seeds/m^2 through to 1000 seeds/m^2 (Figure 5) with the time of sowing 2 (TOS2) plots having the highest initial weed seed populations. This effect carried through to 20 days after emergence with ARG weed populations being consistently (and in some cases significantly) higher in the TOS2 plots (196 plants/m^2 compared with 43 plants/m^2 for TOS1 and 99 plants/m^2 for TOS3) (Figure 6). This effect had however reduced at the 6 week field observations where there was no significant difference between germinated weed populations which averaged 226 plants/m^2 (Figure 7).

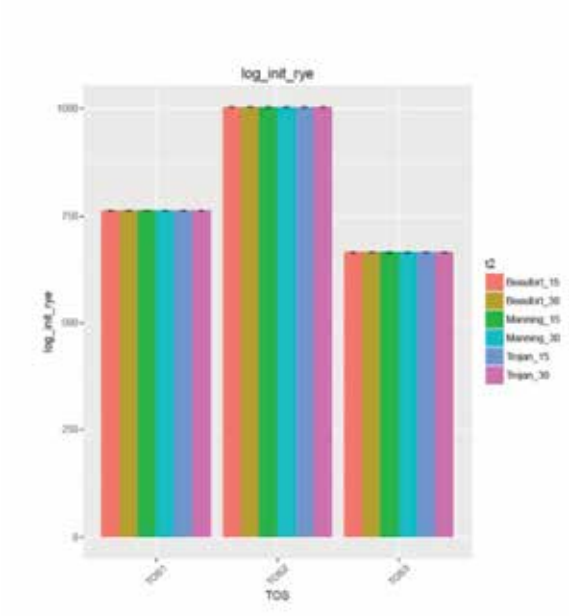

Figure 5: Initial seedbank populations

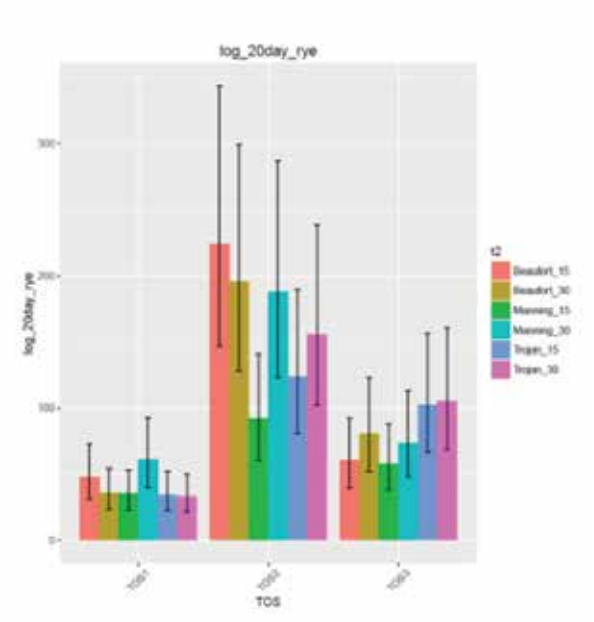

Figure 6: Field weed observations -20 days

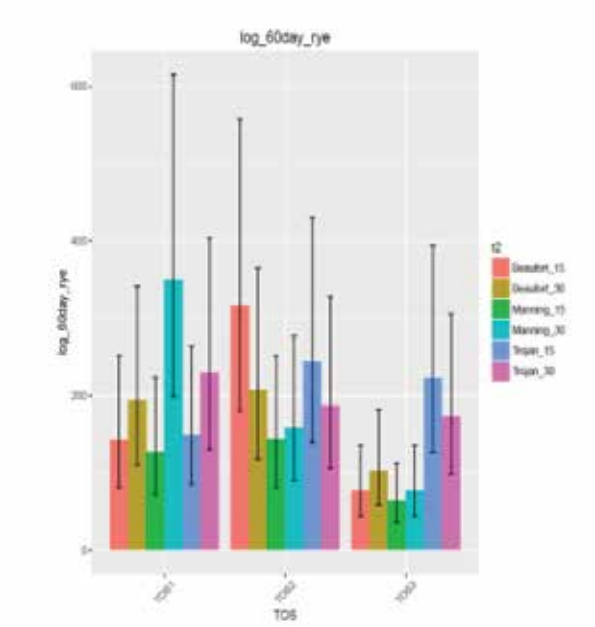

Figure 7: Field observations 6wks

The total ARG seeds collected immediately pre-harvest ranged from 238 seeds/m^2 to 11,750 seeds/m2 (Figure 8); of this only a small percentage (approximately 10%) ended up in the chaff that was collected and sorted during the harvest process (Figure 9). There was no relationship between crop variety, time of sowing and harvest height on these ARG seed numbers.

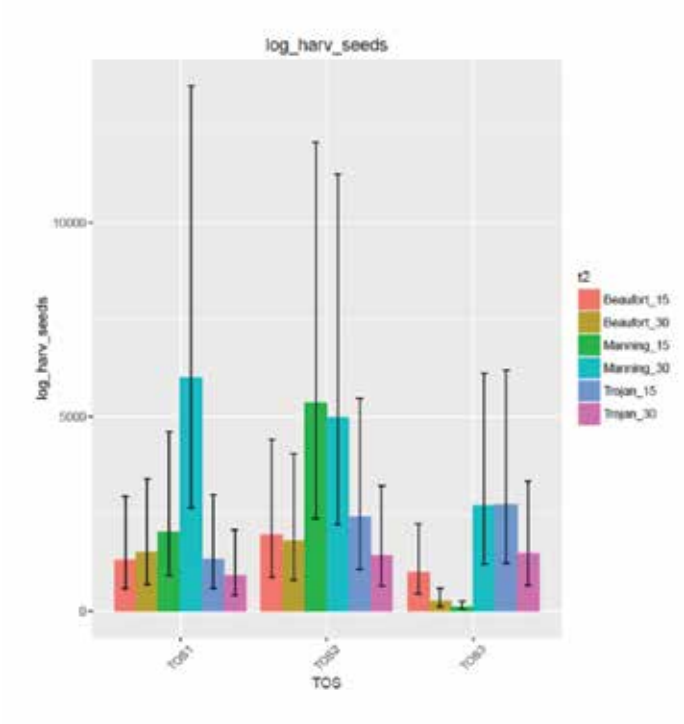

Figure 8: Ryegrass seeds pre-harvest

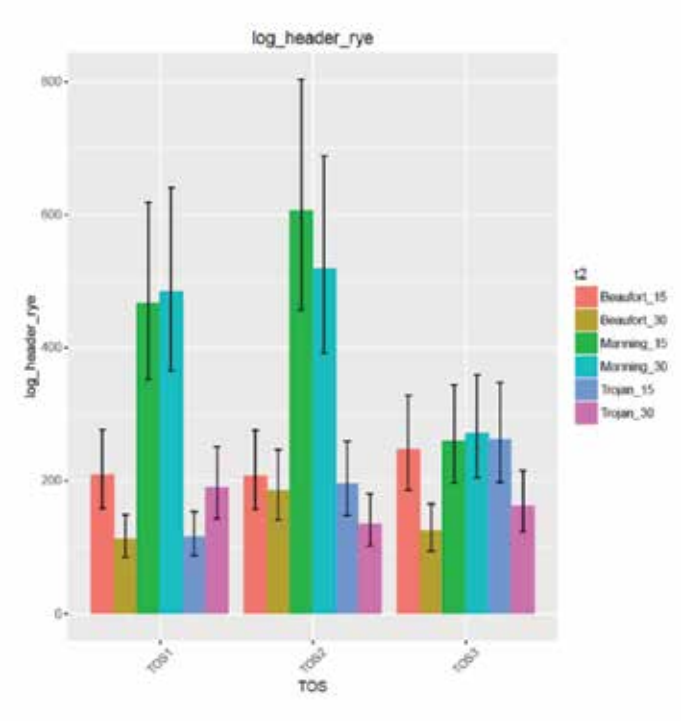

Figure 9: Ryegrass seeds collected in the chaff

Wheat establishment counts were taken 20 days after sowing. In the TOS3 plots, Trojan had a significantly lower plant establishment when compared with different varieties (Figure 10). The wheat was harvested on 22 Dec 2015 with the grain yield of Manning and Trojan significantly reduced between TOS1 and TOS3 (Figure 11). TOS1 (15-May) resulted in maximum yields across all varieties.

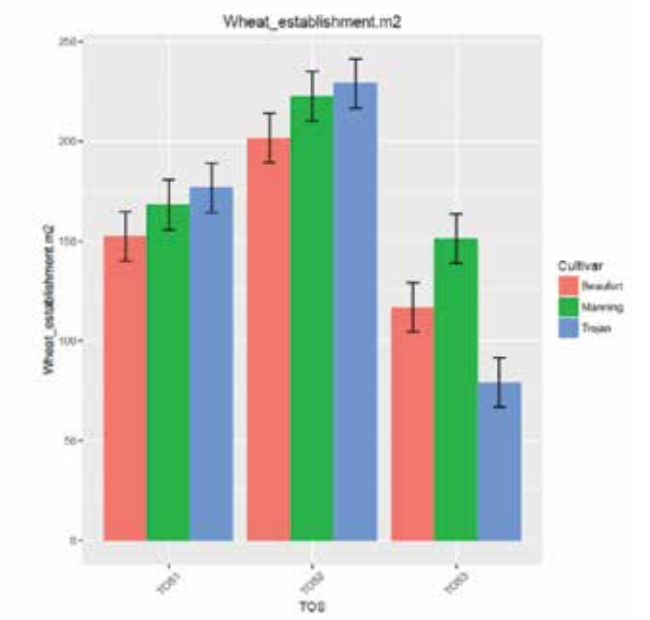

Figure 10: Wheat Crop Emergence (pl/m2)

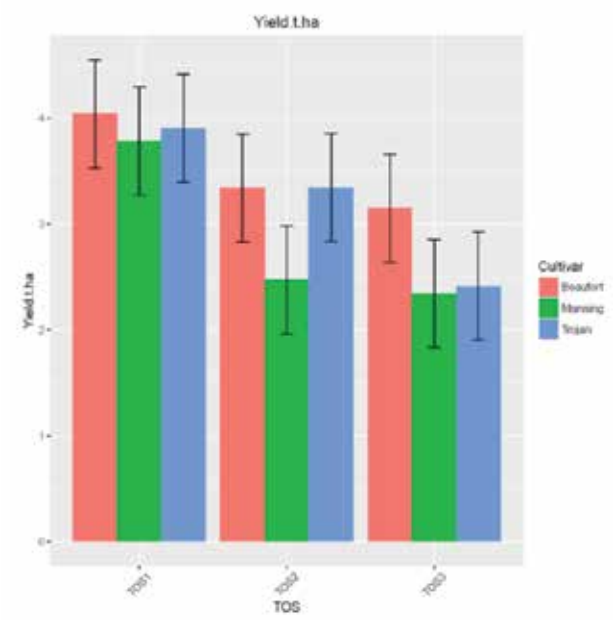

Figure 11: Wheat grain yield (kg/ha)

2016 (Y2)

In 2016, there were no effects of the Y1 treatments seen on weed populations. Initial ARG plants were measured prior to sowing with numbers varying from 142 plants/m^2 to 7536 plants/m^2 and averaging the same as 20015 at 1300 plants/m^2. There was a general trend of lower plant numbers at the TOS3 plots, however this was not significant (Figure 8). Westminster barley was sown across the whole site on 17-May 2016. Figure 9 shows the ARG populations 20days after seeding, and the large variability and lack of a significant difference is shown by the error bars with ARG plant numbers varying from 8 plants/m^2 to 200 plants/m^2. This trend was consistent across all of the ARG data (both plant counts and weed seeds collected in 2016).

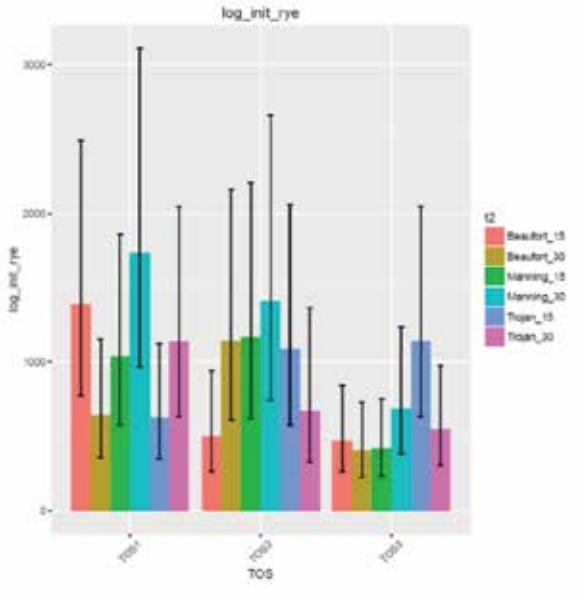

Figure 12: Y2; Initial 2016 ARG plants (pre-sowing)

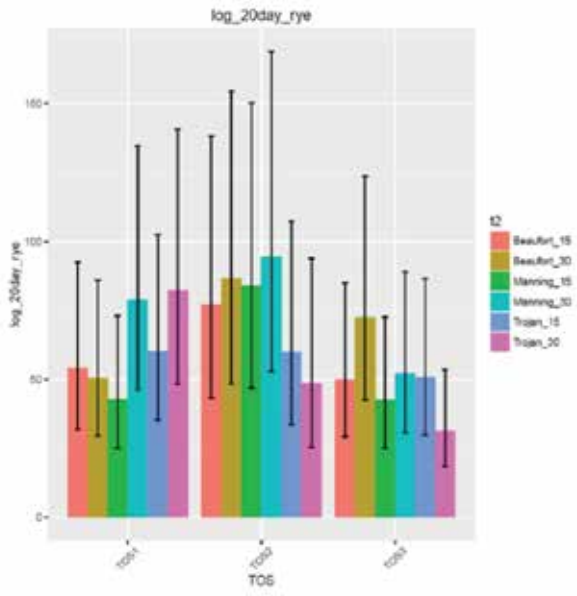

Figure 13: 2016 ARG plants (20 days after sowing)

In 2016, data was collected on the amount of ARG seed shed to further quantify what is being captured by the harvest process and what is being left behind (both in the unharvested fraction and also the seed that has been shed prior to harvest). The ARG reached full maturity in the middle of December between 12-December and 19-December 2016. By 19-December, an average of 2430 seeds/m^2 had been shed and a further 3725 seeds/m^2 had been shed by 29-December.
The plots were harvested on 2-Janury 2017 at which time there was only an average of 3005 seeds/m^2 remaining in seed heads. The plots were harvested at ground level due to extreme crop lodging and so all of these ARG seeds remaining were assumed to be captured (no residue post-harvest). The percentage ryegrass actually captured by the harvest process was calculated at approximately 33% (Table 2).

Barley crop establishment (Figure 14), grain yield (Figure 15) and grain quality were measured. There was no impact of previous treatments observed, with no significant differences in any of these results.

Table 2: Fate of ARG seeds, Conmurra, 2016.

ARG Seed shed		seeds/m^2	
	19-Dec	2430	27%
	29-Dec	3725	41%
TOTAL SEEDS SHED			**67%**
ARG Seeds harvested		seeds/m^2	
	2-Jan	3005	33%
TOTAL SEEDS CAPTURED			**33%**

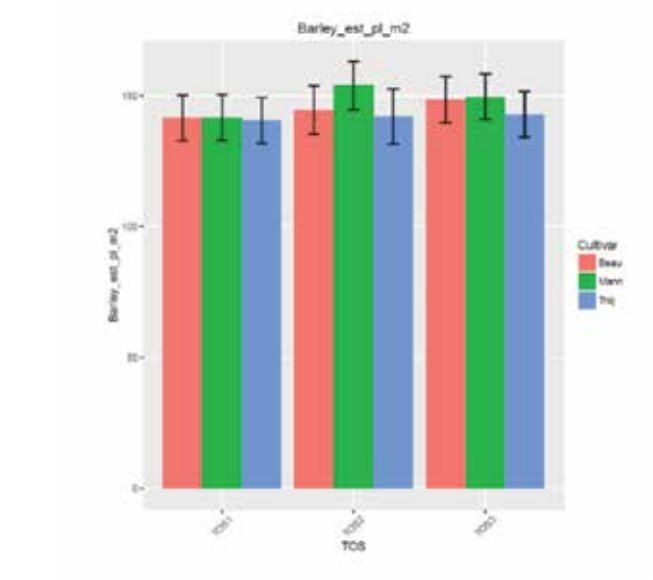

Figure 14: Barley establishment, Conmurra 2016

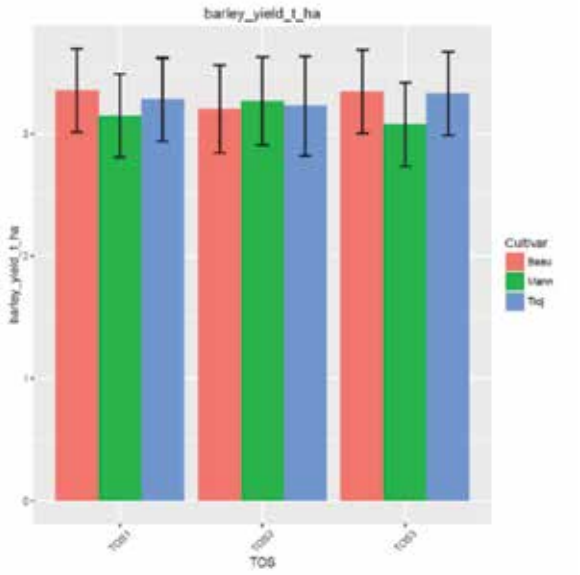

Figure 15: Barley yield, Conmurra 2016

2017 (Y3)

Previous results received at the Conmurra site suggested that the initial plant numbers were so high that any positive impact of harvest weed seed capture (HWSC) techniques were being negated by the ongoing ryegrass weed seed production in traditional cropping systems. In consultation with the other project partners, it was decided to adjust the protocol to look at the impacts of other crop rotations or techniques to try and reduce weed seed levels, and to assess what impact this had on production levels.

In 2017, the three TOS blocks were sown down to Manning wheat, Manning wheat (to be cut for hay) and Westminster barley for hay production. Plant and weed measurements were again taken across the site. Initial ARG populations were 727 plants/m^2 – again with very high variability.

The barley hay was cut on 10-Nov, at which time there were 717 ARG plants/m^2, and the ARG was at Z63 (flowering) – prior to the onset of seed shedding ensuring all ARG seeds in that year were controlled.

The wheaten hay was cut on 4-Dec 2017 – there were 420 plants/m2 present, the ARG was at Z90 and 28,000 seeds/m^2 had already shed (Table 3).

The wheat was harvested on 4-Jan 18, at which time there was 398 ARG plants/m^2 present and a total of 125,000 seeds/m^2 had been shed. These results are summarised in Figure 16.

Table 3: Weed maturity and seed shedding, Conmurra 2017.

	Date						
	3-Nov	10-Nov	24-Nov	4-Dec	13-Dec	21-Dec	4-Jan
Management activity		BARLEY HAY CUT		WHEATEN HAY CUT			WHEAT HARVEST
Zaddocks score (ARG)	59	63	88	90	91	92	93
ARG Seeds Shed (seeds/m^2)			28357	24625	14455	29380	32633

In 2018, the pre-knockdown ryegrass populations were measured. There were an average of 567 ARG plants/m^2 in the barley hay plots, 950 plants/m^2 in the wheaten hay plots and 891 plants/m^2 in the wheat plots.

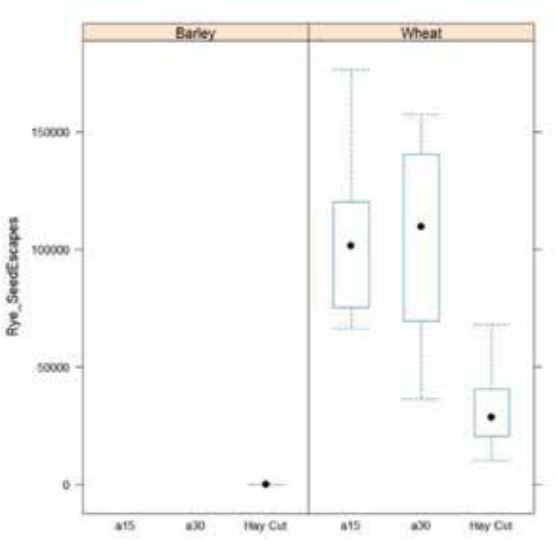

Figure 16: Ryegrass seed escapes by each management zone, Conmurra 2017.

Large scale demonstration site – Furner 2015-16

2015

In 2015, four harvest treatments were imposed; harvesting high at 28cms and burning, harvesting low at 18 cms and; narrow windrow burning, narrow windrow baling and using the iHSD prototype.

The harvest efficiencies were measured across treatments and are shown in Figure 17. Note that there were no significant differences across treatments in grain yield.

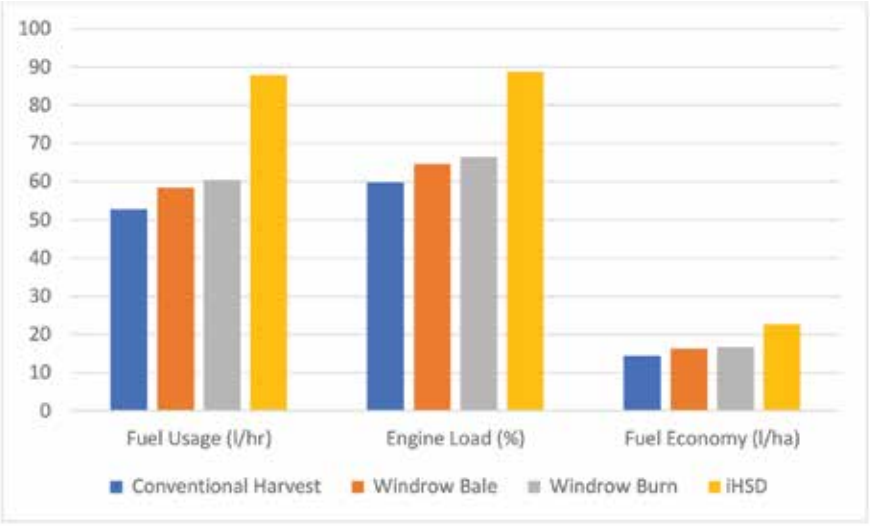

Figure 17: Harvester responses to different harvesting techniques at Furner, January 2016.

ARG measurements were taken immediately prior to harvest with the number of weed seeds above and below the harvest heights of 15cms and 30cms taken to assess the percentage of ryegrass weeds seeds being captured by the harvest process. These results are shown in Table 4.

Table 4: Estimated percentage of ARG seeds captured by the harvest process (2016).

	% ryegrass
Captured seed	
Harvest height at 15cm	52%
Harvest height at 30cm	31%
Uncaptured seed	
(through seed shedding)	48%

The narrow windrow burn and burn treatments were imposed on April 11, 2016. Burning could not begin until later in the day when the dew had lifted, and the windrows would only burn when lit the whole way along, as opposed to being lit at various points along the windrow; this appears to be a common issue in the HRZ and it is not known if the temperatures in the windrow became hot enough to destroy the weed seeds. The fire then spread to the down-wind side of the windrows and only stopped when they reached the fire breaks imposed (Figure 18). Literature from AHRI suggests that once the stubble residue is greater than 4t/ha (2.5t/ha grain yield) then the risk of escape with narrow windrow burning increases. The cereal residues in the south east are usually greater than 4t/ha (even after grazing) and so the use of narrow windrow burning may need to be more crop specific (eg. after a bean or canola crop and not after a cereal crop).

Figure 18: Narrow windrow burning in 2016.

2016

In 2016, the site was sown to broad beans. During the season there was transient waterlogging across the site contributing in part to the high level of variability across the site. No significant difference was found between the harvest treatments in 2015-16 and the weed populations in 2016 (Table 5). There was also no significant difference in grain yield between the hand harvested plants (Table 6). The site was harvested at a single height due to maximise bean yields (the crop was heavily lodged).

Table 5: Weed populations (6 weeks after seeding).

Treatment	total weed plants/m²
Conventional Harvest	102
Weed Seed Mill	66
Windrow Bale Centre	271
Windrow Bale Off Centre	157
Windrow Burn Centre	142
Windrow Burn Off Centre	243
mean	163
P Value(0.05)	0.115
l.s.d	163.1
No sig difference and high cv	*(low confidence in results)*

Table 6: Hand harvested grain yields.

Treatment	Grain yield kg/ha	HI	100 seed weight
Conventional Harvest	4479	0.42	126.2
Weed Seed Mill	4209	0.48	133.6
Windrow Bale	4364	0.42	131.5
Windrow Burn	4255	0.47	135.9
Mean	4326.75	0.45	131.8
P value (0.05)	0.991	0.72	0.58
LSD	2070	0.139	15.89
CV%	13.7	5.2	2.5

The sites were again harvested with a yield monitor to try and gain results around efficiencies at varying heights. As the crop was lodged, it had to all be harvested as low as possible to maximise the grain yield and so there were no differences in harvester efficiencies observed.

Large scale demonstration site – Wolseley 2017

Immediately prior to harvest various weed measurements were taken to assess what percentage of ryegrass weed seeds were being captured by the harvest process. These results are shown in Table 7 with 38% of seeds being below a harvest height of 15cms.

This is expected to be quite variable in the Wolseley environment, and dependent on harvest conditions. Two significant rainfall events (49.8mm from 15-18 November and an additional 29mm on 1 December 2017) was thought by all growers present on the day as a contributing factor to the seed shedding and the percentage of seeds in this medium rainfall environment that had shed. If the harvest height was increased to 30cm, then the number of seeds captured reduced from 62% (at 15cms) to 24% showing the importance of low harvest height to maximise the number of weed seeds being captured.

Table 7: Estimated number of seeds captured by the harvest process, 2017.

	% ryegrass
Captured seed	
Harvest height at 15cm	62%
Harvest height at 30cm	24%
Uncaptured seed (through seed shedding)	38%

The harvest indices were collected from the monitor of each of the two harvesters used at 15cm harvest height where the number of weeds being captured were maximised (one fitted with an iHSD and the other with a narrow windrow chute). These results are shown in Figure 19.

The fuel usage (L/hr) was 14.6% higher in the machine fitted with an iHSD – this equated to a per hectare increase of 37% (11.7L/ha compared to 18.6L/ha). The engine load required increased from an average of 81% to 96%, and the productivity (ha harvested/hour) decreased with the iHSD fitted (5.8 ha/hr to 4.2ha/hr). If the harvest height was lifted to 30cm in the conventional harvester, then productivity increased further to 6.7 ha/hr.

This was a very similar result to what was found with the iHSD prototype used at Furner in 2017.

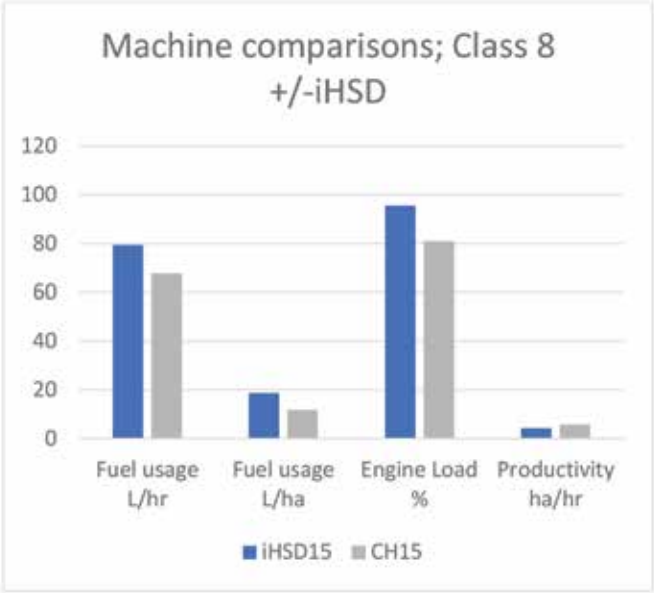

Figure 19: Comparison of two harvesters with and without an iHSD fitted, Wolseley, 2017.

Conclusions

Initial plant numbers were so high in the small plot trials at Conmurra that any positive impact of harvest weed seed capture (HWSC) techniques were negated by the ongoing ryegrass weed seed production in traditional cropping systems. Under these circumstances, alternative crop sequences are required to break the cycle. Barley hay – cut prior to the onset of weed seed shedding was effective in starting to reduce numbers, but additional season (s) are required to reduce to lower levels.

Timeliness of harvest is critical to try and maximise the number of weed seeds captured (prior to the onset of shedding by annual ryegrass). Seasonal conditions are likely to impact on the amount of weed seeds shed.

Harvest height will aid in the capture of increased numbers of ryegrass.

The amount of weed seeds being shed prior to the harvest process are very high and multiple strategies (eg. crop topping or dessication) may be required in the HRZ to manage very high weed burdens.

Still trying to understand the implications of large weed burdens on dynamics in HRZ – this is being further explored in a new GRDC funded project being led by Dr.Chris Preston, University of Adelaide. This will provide further insight into options available to growers in the HRZ.

ACKNOWLEDGEMENTS

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