Harvest weed seed control for the southern high-rainfall zone

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Key messages

- Harvest weed seed control (HWSC) — the collection and/or destruction of weed seeds at harvest — is a non-chemical control method, which can be used to reduce the seedbank of weeds, such as annual ryegrass (*Lolium rigidium*).
- Techniques include mechanical weed destruction, or methods involving carting or baling chaff straight after harvest. Chaff can also be concentrated behind the header in a row, which is then left to mulch (chaff lining or decking) or concentrated in a narrow windrow behind the header and burnt (narrow windrow burning).
- A major premise of HWSC is that the targeted weed species retain a high proportion of their total seed production at crop maturity.
- There was no difference between a harvest height of 30cm and 15cm in terms of the number of weed seeds returned to the soil.
- In wheat crops with high annual ryegrass plant populations, a large percentage of the ryegrass seed matures and drops in the month before wheat harvest, limiting the effectiveness of HWSC in the Riverine Plains region. In 2017, approximately 30% of total ryegrass weed seeds were removed by the harvest process.
- HWSC could be used as one tool in a larger integrated weed management strategy.

Aim

The aim of this work is to understand if growers can reduce soil weed seedbanks in high-yielding high-rainfall zones by adopting harvest weed seed control (HWSC) practices.

Background

The four-year project *Harvest weed seed control for the southern high rainfall zone* (2015–18), aims to investigate the efficacy of HWSC practices across southern Australia through partnerships with Southern Farming Systems, Mackillop Farm Management Group, Riverine Plains Inc and Farmlink Inc. The project included four small plot trials and six on-farm demonstration sites across the different regions.

Riverine Plains Inc was involved in the small plot trial work undertaken to investigate the impact of harvest height on resultant weed seedbanks. The height of the seed on the weed plant in the crop determines the harvest height required to collect most weed seeds.

Method

The Riverine Plains Inc small plot trial was established at Yarrawonga, Victoria during 2016.

Soil weed seedbanks were measured before sowing in 2016. To offset the spatial variability in weed seeds across the paddock, annual ryegrass was sown at varying target densities to reflect commercial grower experiences of: nil (no ryegrass sown), 25 plants/m^2, 50 plants/m^2 and 75 plants/m^2.

In establishing the 2016 trials, the wheat (cv Corack) and ryegrass were sown in two passes on 28 April 2016 into a burnt and levelled wheat stubble, with the ryegrass sown first, followed by the wheat.

The trial was a split plot randomised design. Plots were 2m wide and 15m long. The main plot was harvest height with residue removed (15cm and 30cm) with the sub-plot being ryegrass density. Treatments were replicated five times.

The harvest height treatment was first applied in 2016 (Table 1). The 2017 trial results are analysed based on 2016 harvest heights, with the treatments applied each year described in Table 1.

For the second year of the trial, wheat (cv Trojan) was sown on 12 May 2017, on the same site as the 2016 trial. The same trial design was applied during 2017 as in 2016, though the ryegrass treatments were not re-sown.

In 2017 the site was burnt before sowing and Sakura® was incorporated by sowing (IBS) to provide some ryegrass weed control.

TABLE 1 Wheat stubble height treatment applied from 2015–17

Year	Crop	Stubble height treatment applied at harvest (cm)
2015	Wheat	none
2016	Wheat	15, 30
2017	Wheat	15, 30

The 2017 wheat crop was sown with mono-ammonium phosphate (MAP) at a rate of 75kg/ha. Urea was applied on 4 July 2017 (100kg/ha) and also on 10 August 2017 (100kg/ha).

Soil weed seedbanks were measured on 15 May 2017 by taking five 3cm by 5cm diameter deep soil cores per plot. These cores were planted into small trays and watered regularly. Germinating weed seeds were counted and removed until 15 August 2017.

Annual ryegrass plant populations were measured in the crop when wheat was at the three-leaf stage (GS12) and again when the wheat crop had three tillers (GS23).

Ryegrass seed shedding was measured weekly from 11 November 2017, commencing when the ryegrass was at the mid-flowering (GS65) stage, and continuing until the wheat was harvested on 10 December 2017. Seed shedding was measured by placing two small trays in each plot to catch fallen seeds. Seeds collected in the trays were counted weekly.

At harvest, residue was collected by attaching a fertiliser bulk bag to the back of the plot harvester and regularly unloading straw and chaff away from the plots. The straw and chaff were burnt after harvest. The removal of residue simulates weed seed capture in a broadacre HWSC technique, such as when using a chaff cart.

Data were analysed with an analysis of variance (ANOVA), where data were log transformed for normality if needed.

Results

Harvest height in 2016 did not affect ryegrass numbers in 2017 at either the wheat three leaf (GS13), three tiller (GS23) or the hard dough stages (GS87) (Table 2).

There appeared to be a ryegrass density effect on spikelet numbers, with treatment 1 (ryegrass sown 0/m^2, harvest height 15cm) having a higher number of ryegrass spikelets than treatment 4 (ryegrass sown 75/m^2, harvest height 15cm). This was also observed in the 30cm harvest height treatment, with treatments 5 (ryegrass sown 0/m^2, harvest height 30cm) and 6 (ryegrass sown 25/m^2, harvest height 30cm) having significantly more spikelets than treatment 8 (ryegrass sown 75/m^2, harvest height 30cm). This result, while counterintuitive, may have been caused by the wet conditions experienced during 2016, which caused many of the plots to remain under water for a number of weeks.

Neither harvest height or density affected the number of ryegrass seeds shed (Table 3). Only two treatments were significantly different, with treatment 7 (ryegrass sown 50/m^2, harvest height 30cm) shedding significantly more seeds than treatment 1 (ryegrass sown 0/m^2, harvest height 15cm) and only when measured on 17 November 2017. There was no difference in the total number of seeds shed across treatments.

Harvest height or density did not affect numbers of spikelets above and below harvest height (Table 4).

The mean wheat yield across treatments was 3.10t/ha, while mean protein was 8.08%, mean screenings were 0.68% and the mean test weight was 74.05kg/hL (Table 4). Paddock flooding in 2016 caused the proliferation of ryegrass from the natural seedbank (2016 project protocols stipulated no in-crop weed control), which resulted in high ryegrass populations across all plots in 2017, even in the nil sown plots. These factors, along with the paddock being in its third year of wheat, contributed to the relatively low yield and grain protein results across treatments.

TABLE 2 Germination of ryegrass from soil cores taken 15 May 2017 and ryegrass populations measured in wheat (cv Trojan) at the three leaf (GS13), three tiller (GS23) and dough stage (GS87) stage (all data log transformed) at Yarrawonga, Victoria

2016 treatment	Log ryegrass plants/m^2			Log ryegrass spikelets/m^2
	Soil seed bank	GS13	GS23	GS87
1. Ryegrass sown 0/m^2, harvest height 15cm	1.57^{ab}	1.98	1.92^{ab}	2.31^{a}
2. Ryegrass sown 25/m^2, harvest height 15cm	1.21^{abc}	2.07	2.01^{ab}	2.32^{a}
3. Ryegrass sown 50/m^2, harvest height 15cm	0.77^{abc}	1.96	1.73^{b}	1.94^{ab}
4. Ryegrass sown 75/m^2, harvest height 15cm	0.63^{ab}	2.01	1.98^{ab}	1.45^{b}
5. Ryegrass sown 0/m^2, harvest height 30cm	1.45^{b}	2.00	1.94^{ab}	2.39^{a}
6. Ryegrass sown 25/m^2, harvest height 30cm	1.08^{bc}	2.09	2.04^{a}	2.41^{a}
7. Ryegrass sown 50/m^2, harvest height 30cm	0.65^{bc}	1.98	1.76^{ab}	2.03^{ab}
8. Ryegrass sown 75/m^2, harvest height 30cm	0.50^{c}	2.02	2.01^{ab}	1.53^{b}
Mean	**0.98**	**2.01**	**1.92**	**2.05**
LSD	0.84	n.s.	0.28	0.72

Figures followed by letters are regarded as statistically different (P<0.05).

Note: This data has been log transformed by a factor of 10. Log transformation is used to make highly skewed distributions less skewed in order to conduct statistical analysis. Actual data is presented in Table 5.

TABLE 3 Ryegrass seed shedding measured 10 November 2017, 17 November 2017, 24 November 2017, 10 December 2017; total seeds shed and number of ryegrass spikelets above and below harvest height (24 November 2017) (all data log transformed) at Yarrawonga, Victoria

	Log ryegrass seed shed/m²					Log ryegrass spikelets/m²	
2016 treatment	10/11/17	17/11/17	24/11/17	10/12/17	Total	Above harvest height	Below harvest height
1. Ryegrass sown 0/m², harvest height 15cm	1.98	1.66[a]	2.60	2.82	3.20	1.40[ab]	0.71
2. Ryegrass sown 25/m², harvest height 15cm	2.23	1.98[ab]	2.74	2.67	3.24	1.78[ab]	0.28
3. Ryegrass sown 50/m², harvest height 15cm	2.18	2.30[ab]	2.46	2.56	3.20	1.16[a]	0.54
4. Ryegrass sown 75/m², harvest height 15cm	1.93	2.03[ab]	2.54	2.41	3.06	1.83[ab]	0.67
5. Ryegrass sown 0/m², harvest height 30cm	2.21	1.89[ab]	2.69	2.89	3.21	1.63[ab]	1.02
6. Ryegrass sown 25/m², harvest height 30cm	2.46	2.21[ab]	2.83	2.74	3.25	2.00[b]	0.59
7. Ryegrass sown 50/m², harvest height 30cm	2.41	2.54[b]	2.55	2.63	3.21	1.39[ab]	0.85
8. Ryegrass sown 75/m², harvest height 30cm	2.16	2.26[ab]	2.63	2.48	3.07	2.05[b]	0.98
Mean	**2.20**	**2.11**	**2.63**	**2.65**	**3.18**	**1.66**	**0.71**
LSD	n.s.	0.75	n.s.	n.s.	n.s	0.76	n.s.

Figures followed by letters are regarded as statistically different (P<0.05).

Note: This data has been log transformed by a factor of 10. Log transformation is used to make highly skewed distributions less skewed in order to conduct statistical analysis. Actual data is presented in Table 6.

TABLE 4 Wheat (cv Trojan) plant establishment at the three-leaf stage (GS13), along with 2017 yield, protein, screenings and test weight results, Yarrawonga, Victoria

2016 treatment	Plants/m² (GS13)	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight (kg/hL)
1. Ryegrass sown 0/m², harvest height 15cm	151.11[ab]	3.24	8.14	0.69	74.51
2. Ryegrass sown 25/m², harvest height 15cm	166.22[a]	3.08	8.36	0.76	74.34
3. Ryegrass sown 50/m², harvest height 15cm	157.33[ab]	3.1	8.78	0.68	74.08
4. Ryegrass sown 75/m², harvest height 15cm	154.67[ab]	3.19	8.34	0.73	74.05
5. Ryegrass sown 0/m², harvest height 30cm	138.67[b]	3.13	7.49	0.63	74.13
6. Ryegrass sown 25/m², harvest height 30cm	153.78[ab]	2.97	7.71	0.7	73.95
7. Ryegrass sown 50/m², harvest height 30cm	144.89[ab]	2.99	8.13	0.61	73.69
8. Ryegrass sown 75/m², harvest height 30cm	142.22[ab]	3.07	7.69	0.66	73.66
Mean	**151.11**	**3.1**	**8.08**	**0.68**	**74.05**
LSD	22.85	n.s.	n.s.	n.s.	n.s.

Plant numbers are significantly different (P<0.05) between treatments when followed by different letters.

Wheat plant establishment was significantly lower in treatment 5 (ryegrass sown 0/m², harvest height 30cm) compared with treatment 2 (ryegrass sown 25/m², harvest height 15cm). However this did not have any bearing on yield, protein, screenings or test weight. There were no other significant differences in yield, protein, screenings or test weight across treatments.

Data were untransformed from the log format to show actual ryegrass numbers in the crop (Tables 5 and 6). Ryegrass plant densities ranged from 91–122/m² when wheat was at the three-leaf stage (GS13) and from 54–109/m² when the wheat had three tillers (GS23) (Table 5), suggesting some mortality of the ryegrass.

Seed soil bank measurements taken before sowing showed 3–38 ryegrass plants/m², which was lower than actual ryegrass counts (91–122 plants/m²) when wheat was at the three-leaf stage (GS13). Ryegrass spikelet numbers at the wheat hard dough stage (GS87) ranged from 28–255/m², which equates to between 168 and 1530 seeds/m², based on an estimated average number of six seeds per spikelet.

The number of seeds shed by the ryegrass was measured weekly before harvest. Measurements taken during the second week of November showed that 85–292 seeds/m² were shed; this increased to 254–778 seeds/m² by the first week in December (Table 6). The average total numbers of seeds shed during the four weeks leading up to harvest was 1,596/m², with no treatment effect evident in the log transformed data (Table 3)

In 2017, 30% of ryegrass weed seeds were captured by the harvest process (Table 7). Weed seeds captured were measured as the average number of seeds above header height (15 or 30cm) divided by the total number of weed seeds. The total number of weed seeds was the sum of weed seed shed prior to harvest (Table 6) and number of

TABLE 5 Germination of ryegrass from soil cores taken on 15 May 2017, ryegrass populations measured in wheat (cv Trojan) at the three leaf (GS13), the three tiller (GS23) and the hard dough stages (GS87) and ryegrass spikelets measured at the hard dough stage (GS87) at Yarrawonga, Victoria

2016 treatment	Ryegrass plants/m²			Ryegrass spikelets/m²
	Soil seed bank	Wheat GS13	Wheat GS23	Wheat GS87
1. Ryegrass sown 0/m², harvest height 15cm	38	95	83	204
2. Ryegrass sown 25/m², harvest height 15cm	16	117	103	211
3. Ryegrass sown 50/m², harvest height 15cm	6	91	54	88
4. Ryegrass sown 75/m², harvest height 15cm	4	101	96	28
5. Ryegrass sown 0/m², harvest height 30cm	28	99	88	248
6. Ryegrass sown 25/m², harvest height 30cm	12	122	109	255
7. Ryegrass sown 50/m², harvest height 30cm	4	95	57	106
8. Ryegrass sown 75/m², harvest height 30cm	3	106	102	34

TABLE 6 Ryegrass seed shedding counts on 10 November 2017, 24 November 2017, 10 December 2017, along with total number of seeds shed at Yarrawonga, Victoria

2016 treatment	Seed shed/m²				
	10/11/17	17/11/17	24/11/17	10/12/17	Total
1. Ryegrass sown 0/m², harvest height 15cm	96	46	396	656	1596
2. Ryegrass sown 25/m², harvest height 15cm	171	94	547	465	1730
3. Ryegrass sown 50/m², harvest height 15cm	152	201	288	361	1583
4. Ryegrass sown 75/m², harvest height 15cm	85	106	343	254	1145
5. Ryegrass sown 0/m², harvest height 30cm	163	78	488	778	1636
6. Ryegrass sown 25/m², harvest height 30cm	292	162	675	551	1774
7. Ryegrass sown 50/m², harvest height 30cm	258	345	355	428	1624
8. Ryegrass sown 75/m², harvest height 30cm	144	182	424	302	1174

weed seeds above and below header cutting height, as measured on 24 November 2017.

Observations and comments

At the outset of this project it was expected that lowering harvest height from 30cm to 15cm would increase the amount of weed seed captured during the harvest process and this would reduce the number of seeds returned to the seedbank. However, 2017 plant population measurements showed no statistical evidence to indicate the 15cm harvest height applied during 2016 decreased ryegrass plant numbers compared with the 30cm harvest height.

High weed numbers in 2016, along with high rates of lodging, meant weed seeds at both harvest heights were difficult to pick up with the header front. Also, the high amount of ryegrass seed shed before the 2016 harvest (on average 4,824/m²), reduced the effectiveness of HWSC techniques.

In instances where weed numbers are low and/or there is still a significant amount of ryegrass retained in the head of the grass weed at harvest, it seems logical to harvest as low as possible to get as much seed through the header to be captured and destroyed.

During both 2016 and 2017, soil weed seed banks were measured by taking soil samples and growing them out in trays. In both years, weed germination rates in the trays were lower than the actual germination rates recorded in the paddock, indicating that this method tends to underestimate the level of the weed seedbank.

Although more ryegrass weeds germinated during 2017 compared with 2016, these ryegrass plants produced less

TABLE 7 Ryegrass spikelets and seeds captured by the harvest process at Yarrawonga, Victoria 2017

Average ryegrass spikelets above header cutting height	Average ryegrass seeds above header cutting height	Average spikelets below header cutting height	Average seeds below header cutting height	Average seeds shed prior to harvest	Total ryegrass seeds	Seeds captured by header
(spikelets/m²)	(seeds/m²)	(spikelets/m²)	(seeds/m²)	(seeds/m²)	(seeds/m²)	(%)
124	744	19	114	1596	2454	30

Note: Ryegrass seeds/m² were calculated by multiplying the number of ryegrass spikelets/m² by six.

seed overall by the soft dough stage (GS87) than during 2016 (Table 8). It appears that during 2017 some ryegrass plant mortality occurred between the three-leaf stage (GS13) in wheat and the three-tiller stage (GS23). The surviving plants produced fewer spikelets and less seed (Table 8). Lower ryegrass weed competitiveness during 2017 could be due to a number of factors including the application of HWSC during 2016 and the use of an IBS herbicide during 2017 (not used during 2016). The 2017 wheat crop was also less stressed and generally more competitive than the 2016 wheat crop, which was affected by flooding throughout the growing season.

To date, much of the data on ryegrass weed populations has been collected in the low-to-medium rainfall zones, however data collected through this project relates specifically to the medium-to- high rainfall zone.

The results from this project suggest that applying HWSC techniques will be more effective in paddocks with low-to-medium ryegrass weed densities, paddocks where the crop and weeds have not lodged and in crops with a maturity date closer to the maturity date of the ryegrass.

In wheat paddocks with high ryegrass burdens, HWSC is not recommended as a single weed control strategy and should be integrated as part of a wider weed management strategy.

TABLE 8 Comparison of 2016 and 2017 ryegrass numbers in wheat (cv Trojan) at the three leaf (GS13), three tiller (GS23) and soft dough (GS87) stages, along with total numbers of seeds shed

Crop growth stage	2016	2017
	Ryegrass density (plants/m^2)	
Ryegrass at wheat GS13	56.57	103.17
Ryegrass at wheat GS23	76.52	82.73
Spikelets at wheat GS87	803.93	147
Total numbers of seed shed	4824	1596

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