MANAGING ANNUAL RYEGRASS in the High-Rainfall Zones of Victoria, South Australia and Tasmania

September 2021

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Title:
Managing Annual Ryegrass in the High-Rainfall Zones of Victoria, South Australia and Tasmania

ISBN:
978-1-922342-21-8 (online)
978-1-922342-22-5 (print)

Project details:
SFS1904-003 – Integrated weed management of herbicide-resistant annual ryegrass at Lake Bolac.

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Published: September 2021.

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Design and production:
Coretext, www.coretext.com.au

COVER: Mature ryegrass in barley.
PHOTO: Nicole Baxter

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INTRODUCTION

What's challenging in the HRZ?

Key messages

- Annual ryegrass in the high-rainfall zone (HRZ) is as competitive as in lower-rainfall environments, with each ryegrass plant reducing cereal yield potential by about 0.3 per cent. There is no benefit to tolerating more weeds in the HRZ than in other environments.
- Pre-emergent herbicides are important tools for annual ryegrass management in the HRZ and are more effective when used in mixtures and sequences than when used alone.
- Crop competition is an important tool for ryegrass management in the HRZ in canola and cereals. Reduced competition results in large annual ryegrass seed production.
- Double-breaks aid in the reduction of annual ryegrass seed production through the ability to include additional tactics to target the weed in consecutive years.
- With a large number of missed weed seeds due to later harvests, harvest weed seed control (HWSC) is less effective in the HRZ. However, it can still play an important role when integrated with other tactics. Ensure extra costs are less than $34 per hectare.
- The best results in terms of both annual ryegrass control and profitability come from stacking multiple tactics each season over several seasons. Extra income from better weed management is obtained in favourable years and more than compensates for less-favourable years.

Managing annual ryegrass in an economical and sustainable way has been a significant challenge for many years in the high-rainfall zone (HRZ) cropping paddocks of the south-eastern grainbelt. However, the challenge has increased in recent years.

There is now widespread resistance to post-emergent herbicides and increasingly to other important herbicides such as glyphosate, which places heavier reliance on pre-emergent herbicides. However, annual ryegrass germinates throughout winter into spring, which challenges the ability of early season herbicide strategies to control it.

The cool and wet growing season of the HRZ drives high productivity in both crops and weeds. Annual ryegrass weeds that survive until maturity are able to produce large amounts of seed, causing populations to rebound quickly from control efforts. Heavy crop stubble loads create trade-offs between effective harvest weed seed control at low cut heights and efficient harvest and sowing operations.

However, recent research and industry practices have pointed to strategies that can be used to improve annual ryegrass management in the HRZ. This booklet summarises that progress and provides a go-to resource for implementing the gains. While there is still more work to be done, this booklet is intended to assist growers to implement current best practice in annual ryegrass control in the HRZ and to inspire further development in the area.

Acknowledgements

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

Southern Farming Systems wishes to express its sincere gratitude to Neil and Graeme Vallance, who were the hosts of the Lake Bolac site for the nine years of the long-term trial. The unique dataset is available to the industry thanks to their remarkably faithful collaboration.

The Ridgway and Williams families are thanked for the contribution of their time and resources to the cereal windrowing trials, along with James Heffernan (Nutrien Naracoorte), whose guidance and advice was greatly appreciated.

The teams at Southern Farming Systems and MacKillop Farm Management Group are thanked for their efforts in managing the trials discussed in this booklet.

PRE-EMERGENT HERBICIDES

What's working, what isn't and what's next?

Key messages

- Pre-emergent herbicides are essential for annual ryegrass control in the HRZ.
- Ideal products are those with greater persistence and lower water solubility.
- Mixtures work better than individual products, particularly on high annual ryegrass populations.

The increasing extent of resistance in annual ryegrass to post-emergent herbicides in the HRZ means there is more reliance on pre-emergent herbicides for grass weed control. There are several major challenges with using pre-emergent herbicides in the HRZ. These are:

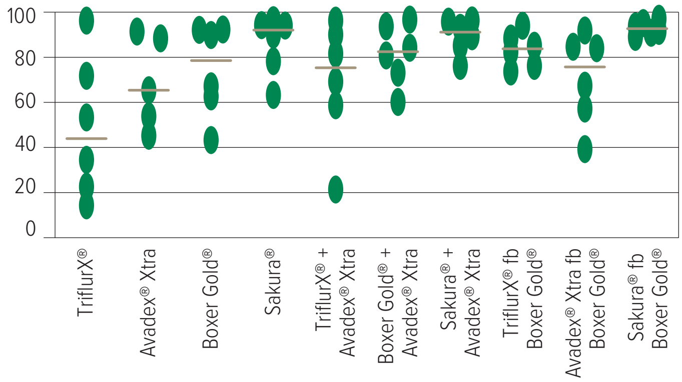
1. **Long seasons.** The pre-emergent herbicide can dissipate before annual ryegrass completes its emergence.
2. **High rainfall and waterlogging.** Large rainfall events can move some pre-emergent herbicides into the root zone of the crop causing crop damage, or below the root zone of the weeds. Waterlogging can make it more difficult for the crop to recover from herbicide effects.
3. **High weed numbers.** High weed numbers are always a challenge for pre-emergent herbicides.
4. **Herbicide resistance.** This makes certain pre-emergent herbicides ineffective and can compromise mixes containing these herbicides.

The best products will be those herbicides that have lower solubility and longer persistence. All the available pre-emergent herbicides can provide good early control of annual ryegrass, but the more persistent products will provide control later in the season. Options such as trifluralin and pyroxasulfone (Sakura®) fit these characteristics well.

Research trials in the HRZ have shown mixtures of pre-emergent herbicides often work better than the use of single products for the control of ryegrass. The data in Figure 1 is from a set of six trials conducted in high-rainfall areas of south-eastern Australia that looked at individual pre-emergent herbicides, mixtures and sequences. Efficacy was measured by counting annual ryegrass seed heads at harvest. While all herbicides could control annual ryegrass well under the right conditions, single herbicides failed more often, whereas mixtures tended to be more robust. When the pre-emergent is less effective it results in high weed seed-set.

The availability of new pre-emergent herbicides with different modes of action offers new options to manage annual ryegrass across more crops. Most of the newer pre-emergent herbicides also work well in mixtures with the older products. However, mixtures of Luximax® with Boxer Gold® or Sakura® should not be used as these mixtures lead to unacceptable crop damage.

Figure 1: Comparison of various pre-emergent herbicide products applied alone, in mixtures and in sequences for the control of annual ryegrass in wheat in six trials across south-eastern Australia in 2011 and 2012.*



* The average control for each herbicide is represented by a single dot for each trial and the line is the mean across all six trials. Trials were conducted at Yarrawonga and Lake Bolac, Victoria, Wagga Wagga, NSW, and Manoora and Saddleworth in SA. 'fb' in the mix names indicates the second herbicide was applied early post-emergent at the one-leaf annual ryegrass growth stage (GRDC Code UA00113).

Figure 2: Sequences of pre-emergent herbicides can improve annual ryegrass control. On the left is TriflurX® pre and right is Sakura® pre followed by Boxer Gold® early post.

Photo: Christopher Preston

CASE STUDY:

Agronomist perspective – Jason McClure, Elders Naracoorte, SA

Annual ryegrass is the most widespread and significant weed in the high-rainfall zones where I provide advice. It is pretty common to see resistance to post-emergent grass herbicide in cereals and increasing resistance to the post-emergent options in pulses and canola.

To manage ryegrass in our area I advise clients to reduce ryegrass numbers at every opportunity. Clients use and integrate several chemical and mechanical techniques including crop-topping, stubble burning and windrow burning, harvest weed seed destruction, crop rotation and pre-emergent herbicides. Pre-emergent herbicides are the most commonly used of all these techniques.

Prior to the release of Boxer Gold® and Sakura® (approximately 10 years ago), trifluralin and Avadex® Xtra were our most relied upon pre-emergent herbicides, which caused widespread resistance to develop. Sakura® has become the key pre-emergent in wheat because it gives 8–10 weeks' residual control of annual ryegrass, while Boxer Gold® is predominantly used in the barley rotation.

The triazines and propyzamide are key pre-emergent herbicides used in our canola and pulse crops. The crop rotation in our area allows us to alternate and use different modes of action (MOA) across different crops from season to season.

In paddocks with a higher ryegrass population, increased known resistance, and/or where crop rotations are tighter, it is recommended to mix different MOA – for example, Sakura® and Avadex® – to increase the level of pre-emergent ryegrass control. However, it is just as critical to use the full label rate of both herbicides when mixing different MOA, as reducing or cutting rates will only lead to resistance to one or both herbicides.

There are several new pre-emergent herbicides coming onto the market including Overwatch®, Voraxor®, Luximax®, Mateno® Complete (not registered at time of writing) and Ultro®, which have a different MOA. I propose to rotate these MOA into our cropping plans and will also recommend different combinations of these herbicides to prevent or at least delay the onset of resistance in annual ryegrass.

Photo: James Manson

Figure 3: Annual ryegrass emerging in oats near Berrybank in Victoria. Pre-emergent herbicide mixes provide better control than single-product strategies.

CROP COMPETITION

Does it really matter?

Key messages

- Increasing the competitiveness of a crop can increase grain yield and benefit future phases of the rotation by reducing annual ryegrass seed-set.
- Annual ryegrass is just as competitive in the HRZ as it is in lower-rainfall environments. Every three annual ryegrass plants per square metre present in late winter reduce cereal yield potential by about one per cent.
- Crop competitiveness can be increased by sowing earlier, using adequate or increased sowing rates and choosing more competitive cultivars.

Weed competitiveness and crop yield

There has been uncertainty about whether weeds are more competitive in the HRZ than in lower-rainfall zones. Based on the observations that many HRZ paddocks have high annual ryegrass burdens but are also high yielding, some have concluded HRZ crops can tolerate the presence of weeds. The practical application of this theory would be to raise the threshold for a ‘problem’ weed burden.

Research has now demonstrated that although the HRZ is an environment that produces more biomass than lower-rainfall zones, both crops and weeds grow more vigorously without favouring one over the other. Figure 4 shows the equation that models the ratio of crop to weed competition in the RIM (Ryegrass Integrated Management) weed management decision tool (developed largely in lower-rainfall zones) works well for wheat and barley in the HRZ.

What this shows is that yield loss due to weeds as a percentage of yield potential is similar in both low and high-rainfall zones. Therefore, there is no benefit in tolerating more weeds in the HRZ. See Figure 6 and the discussion following for an example that supports this dynamic in canola.

This is valuable knowledge for understanding the dynamics of annual ryegrass ecology in HRZ farming systems. It also informs business decisions about weed management in a few ways.

- First, for every three annual ryegrass plants/m^2 present in late winter in a cereal paddock, potential yield will be reduced by about one per cent. This rule of thumb can be used to inform likely returns on investment in weed management and to correct an estimated yield potential prediction if weed control is suboptimal.
- Second, cereal crops in the HRZ have more yield to lose from weeds than in lower-rainfall environments due to the higher weed numbers, but also more to gain by controlling weeds. For example, if the yield potential of a cereal crop is three tonnes per hectare, then the penalty caused by 30 annual ryegrass plants/m^2 will be 0.3t/ha. However, if the yield potential is 6t/ha, then the penalty will be 0.6t/ha. Therefore, HRZ growers can invest more in annual ryegrass management than their lower-rainfall counterparts and obtain greater returns.
- Third, while HRZ growers can remain profitable with high weed burdens because of the buffering effect of their high yield potential, they should not accept an annual ryegrass burden of any size because controlling these weeds will increase profitability.

System benefits from crop competition

Growers may delay sowing and reduce sowing rates for various reasons. However, current research would suggest these practices have significant negative effects on grain yield and weed management through reducing crop competition. Crop competition not only benefits the current crop in a rotation but can also benefit future crops by reducing annual ryegrass seed-set.

For example, in a farm-scale trial at Lake Bolac in 2019, a reduction in crop competition caused by a suboptimal sowing rate of SF Ignite TT canola reduced yield and increased annual ryegrass seed-set. The sowing rate treatments had 20 or 45 plants/m^2 and were applied to three herbicide treatments of low, medium and high-cost herbicide strategies (see section ‘Using rotations and stacked tactics’).

Figure 4: The weed damage function in the Ryegrass Integrated Management (RIM) and Land-Use Sequence Optimiser (LUSO) models accurately predicts wheat and barley yields in HRZ environments with the number of annual ryegrass plants/m^2 in late winter. The solid line is the 1:1 ratio (GRDC Code SFS1507-003).

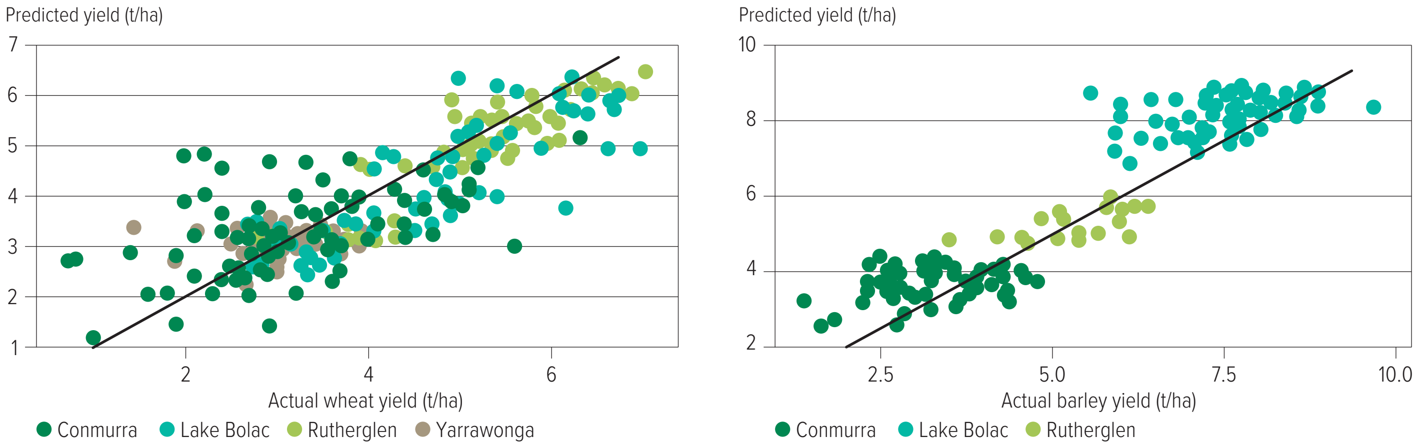


Figure 5: Annual ryegrass heads pushing through a wheat canopy. Crop competition can reduce weed seed-set.

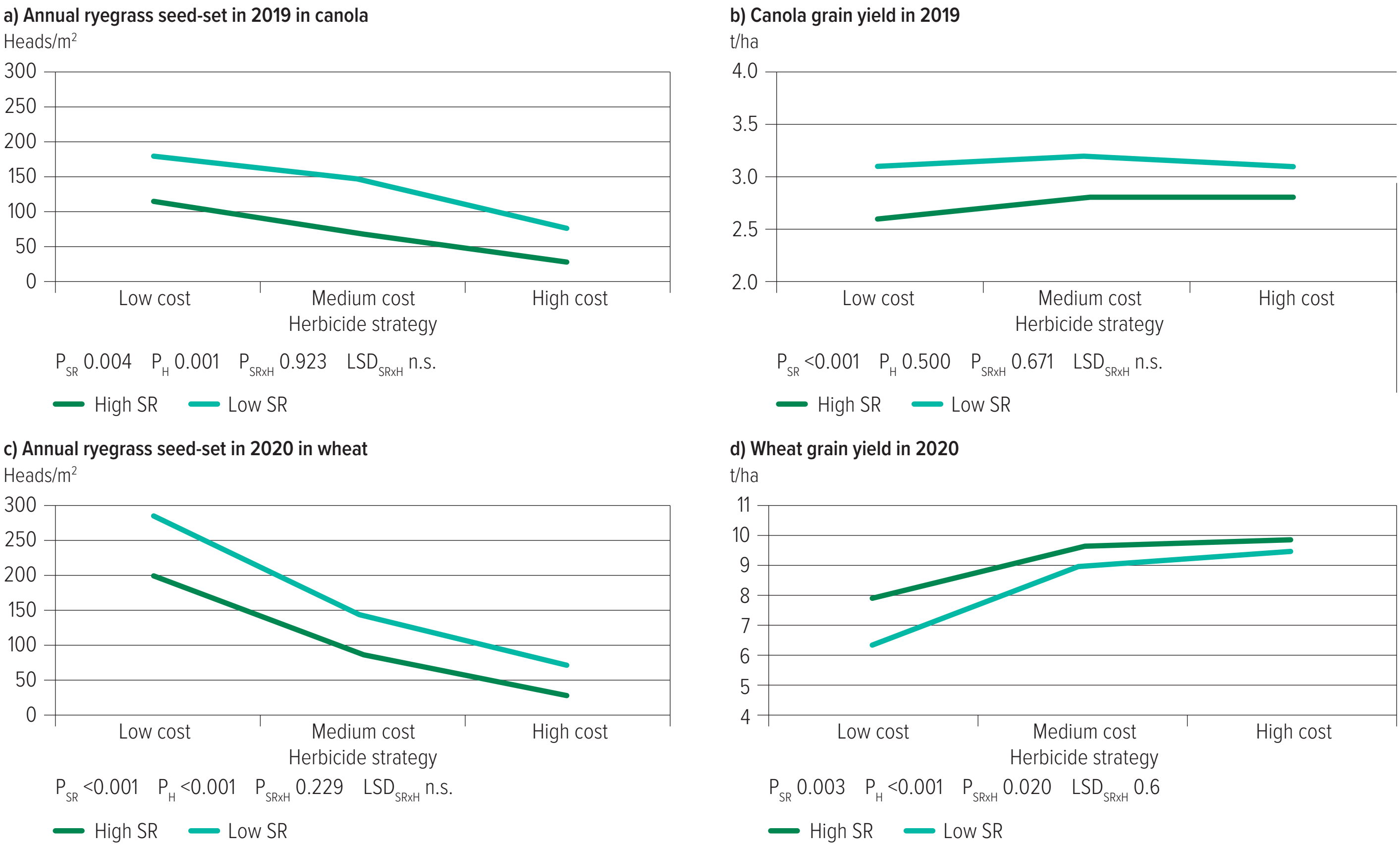
Photo: James Manson

With each herbicide treatment the crop competition provided by the hybrid canola canopy at the optimal sowing rate reduced annual ryegrass seed-set as measured by annual ryegrass heads/m^2 (Figure 6a). The reduction in crop numbers in the low sowing rate also resulted in a reduction of yield of an average of 0.4t/ha (Figure 6b). Hybrid canola is more vigorous than open-pollinated cultivars, but adequate plant numbers were still required for yield and competition against ryegrass.

In 2020, two wheat sowing rates that achieved plant densities of 150 plants/m^2 and 200 plants/m^2 were used, with 2020 sowing rate plots matched to the 2019 canola sowing treatments. A higher wheat sowing rate in 2020 maintained the smaller size of the weed burden from 2019 (Figure 6c) and produced greater yield than the lower sowing rate (Figure 6d). Crop competition complemented all herbicide strategies for weed control in both years.

Therefore, maintaining high crop competition through sowing early, using adequate sowing rates and choosing competitive cultivars allows a high yield potential in the current year and can also protect the yield potential of a paddock for future years. Reducing crop competition can compromise the current year's crop as well as the yield potential of subsequent crops in the paddock.

Figure 6: The effect of crop sowing rate on annual ryegrass seed-set and grain yield in canola and wheat using different herbicide strategies and cost (GRDC Code SFS1904-003).



SR = sowing rate; H = herbicide strategy; SRxH = interaction of sowing rate and herbicide strategy.
P values less than 0.05 indicate that the experimental effect (herbicide or sowing rate or the interaction between the two) was significantly different.

STACKING WEED MANAGEMENT TACTICS IN PRACTICE

How much pressure is needed to stay on top of the seedbank?

Key messages

- Stacking tactics are essential for long-term control of annual ryegrass in the HRZ.
- Effective pre-emergent herbicides followed by an in-crop tactic and a tactic to reduce seed return to the soil should be implemented in as many phases of the rotation as possible.
- The economic benefits of additional weed control tactics are less in lower yielding years but increase in higher yielding years.

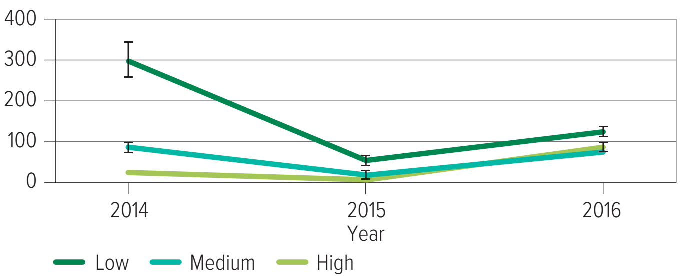
Trial at Frances SA, 2014-2016

Individual tactics are insufficient for controlling annual ryegrass in the HRZ. Therefore, stacking of tactics within crop years is required. The question often comes down to how many tactics need to be used to control annual ryegrass, the level of herbicide resistance and what effect that has on profitability.

A three-year trial conducted at Frances, SA, from 2014 to 2016 looked at the impact of increasing intensity of weed control practices in a canola/wheat/faba bean rotation. The lowest-intensity strategy included pre and post-emergent herbicides in the canola and faba bean years and just a pre-emergent herbicide in the wheat year. The other strategies added included herbicide tactics and crop-topping (Table A1, see Appendix).

Annual ryegrass spike numbers at harvest were highest for the low-intensity management strategy and lowest for the high-intensity management strategy. However, there was no difference in 2016 between the medium and high-intensity management strategies (Figure 7).

Figure 7: Annual ryegrass spike numbers at harvest at Frances, SA, from 2014 to 2016. The three-year rotation comprised canola/wheat/faba beans. Three management intensities were employed in each year (GRDC Code UCS1306-001).



Reduced annual ryegrass populations with the highest-intensity management resulted in higher yields in faba beans and wheat compared with the lowest-intensity management (Table 1). Profitability was lowest with the low management intensity due to the yield lost to weed competition. This strategy lost $158/ha to $184/ha over three years compared with the other strategies. There was no difference in profitability between the medium and high management strategies. The years 2014 and 2015 were drier than normal seasons, depressing crop yields. The increase in yield was not sufficient to cover the extra cost of weed control in the high-intensity management strategy.

Table 1: Yield and cumulative gross margin* for the three crops at Frances, SA, from 2014 to 2016 (GRDC Code UCS1306-001).

Management strategy	Yield (t/ha)#			Cumulative gross margin ($/ha)
	2014	2015	2016	
Low	1.8	1.7 b	3.4 b	$1815
Medium	2.0	1.8 ab	3.7 ab	$1999
High	1.9	1.9 a	3.9 a	$1973

* Gross margin = yield x price minus costs.
# Different letters indicate a significant difference based on the LSD (P<0.05).

Figure 8: Annual ryegrass heads emerging above a barley crop. An in-crop and a late season (for weed seed control) tactic should be added to pre-emergent herbicides for the best results.

Trial at Frances SA, 2019-2020

A trial with four management intensities was conducted at Frances from 2019 to 2020. In this trial four management strategies (MS 1 to MS 4) were used, ranging from low intensity to high intensity in each cropping year (Table A2, see Appendix). Strategies included a mix of herbicides and non-chemical practices.

Across the two years, annual ryegrass populations increased in MS 1 and MS 2; however, MS 3 and MS 4 kept annual ryegrass numbers low (Figure 9). At the end of the trial, there was no difference between MS 3 and MS 4 in annual ryegrass populations, but both were significantly lower than MS 1 and MS 2. Sowing on wider rows in wheat in 2019 resulted in higher weed populations (Figure 10) and increased weed seed-set. This illustrates the importance of crop competition in reducing annual ryegrass seed production in the HRZ.

The lower annual ryegrass numbers in-crop led to increased crop yield in each year. MS 4 had the highest yield in both years and MS 2 had the lowest yield (Table 2). MS 2 had the lowest gross margin across years and MS 4 had the highest gross margin, despite being the most expensive management strategy. The gross margin for MS 4 was more than $400/ha greater than MS 2 across the two years.

Table 2: Yield for wheat in 2019 and faba beans in 2020 at Frances, SA, with four management strategies (MS 1 to MS 4) and cumulative gross margins for each management strategy across each given year.

Management strategy	Yield (t/ha)#		Cumulative gross margin ($/ha)
	2019	2020	
MS 1	6.2 c	3.8 ab	$3772
MS 2	6.2 c	3.5 b	$3642
MS 3	6.7 b	3.9 ab	$3926
MS 4	7.1 a	4.0 a	$4072

Different letters indicate a significant difference based on the LSD (P<0.05)

Across these two trials, improving annual ryegrass control resulted in higher crop yields and gross margins. In higher-yielding crops, the most intense management strategy was the most profitable. However, in lower-yielding crops, the increase in yield did not cover the extra costs of control. Overall, there was a benefit to stacking additional tactics for annual ryegrass control.

Figure 9: Annual ryegrass populations at Frances, SA, from 2019 to 2020 under four different management strategies (MS 1 to MS 4). Weeds were counted in each year after in-season management tactics were concluded.

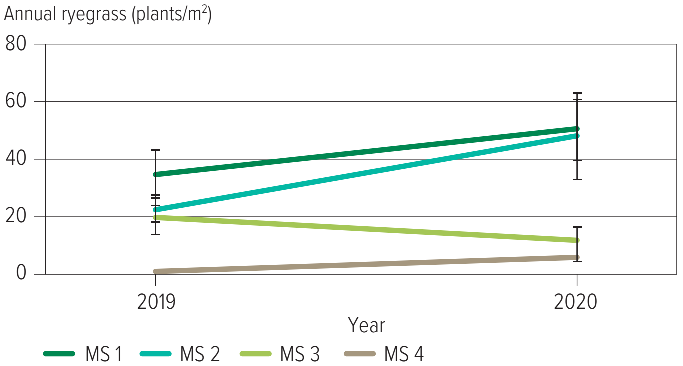


Figure 10: Effect of wheat row spacing on annual ryegrass in crop. Shown above is wide row spacing of 42cm; below is narrow row spacing of 21cm.

Photos: Christopher Preston

The best approach to stacking tactics was to include a robust pre-emergent herbicide package, to have some control tactics in-crop and to reduce seed return to the seedbank at the end of the season. In these trials crop-topping was used for annual ryegrass seed-set control, but this can be replaced by non-chemical tactics such as HWSC (see later section, 'Harvest weed seed control in the HRZ').

CASE STUDY:

Brett Gilbertson, Rendelsham, SA

Brett Gilbertson runs Gilbrae, his mixed farming enterprise comprising sheep, cattle and cropping, in Rendelsham, SA. He sows approximately 1700ha to wheat, barley, canola, broad beans, strawberry clover and carrots for seed. Several tools are used to manage ryegrass at Gilbrae. Brett's main aim is to stack a combination of tools to achieve the best ryegrass control. One tactic used is to cultivate paddocks pre-sowing. He also uses a mouldboard plough, which buries ryegrass seeds to a depth where they are broken down after four to five years. Brett says tillage is still a major part of Gilbrae's system and works well in this environment. Where he can, he uses a double-knock approach to pre-season herbicide use to reduce the chance of glyphosate resistance developing. He is excited about the new pre-emergent chemistry and mode of action groups that are becoming available and he is having a look at Overwatch® this year (2021). For the past three seasons Gilbrae has had a Harrington Seed Destructor fitted to one of its two harvesters to capture as many weed seeds as possible at harvest. Brett has greater trust in the machinery since the inclusion of blockage sensors. Finally, paddocks where ryegrass is particularly problematic are selected to be cut for silage.

USING ROTATIONS AND STACKED TACTICS

A long-term perspective from Lake Bolac

Key messages

- In a long-term annual ryegrass trial at Lake Bolac, increasing the average herbicide cost from $39/ha/year to $85/ha/year increased profitability by $179/ha/year after nine years.
- A double-break of faba beans followed by canola decimated the size of an exponentially increasing annual ryegrass population because of the stacking of pre-emergent herbicides followed by post-emergent herbicides and crop-topping.
- The best outcomes for annual ryegrass management occur where robust herbicide packages are paired with crop rotations that utilise break crops and double-break strategies effectively.

Long-term IWM trial at Lake Bolac, Vic. 2012-2020

From 2012 to 2020 a unique integrated weed management (IWM) trial was conducted at Lake Bolac to explore the effects of combining cultural and herbicide control strategies across a rotation. Three herbicide strategies that differed in cost (low cost, medium cost, high cost, see Appendix, Table A3) were applied to 20 metres wide by 60m long plots for the nine-year duration of the trial. Cultural control treatments were assigned to main plots and herbicide treatments were assigned to the sub-plots, which were not randomised due to practical constraints. The trial consisted of four replicates.

The data from the nine years of herbicide treatments is presented in Table 3, having taken the average from all cultural control treatments. It was rare for the effect of a herbicide to depend on the cultural treatment used. Earlier in this booklet, in Figure 6 in the section 'Crop competition', data showing the effects of crop sowing rate and herbicide strategy was presented from the final two years of this trial.

The effect of a double-break on annual ryegrass control

The strategies used from 2012 to 2015 failed to reduce annual ryegrass numbers. With the highest-cost strategy annual ryegrass populations increased slowly and in the other strategies the populations increased more quickly. Therefore, a double-break of faba beans followed by canola was included in the rotation (Figure 11).

This provided two consecutive seasons of being able to include multiple tactics for annual ryegrass control where a crop-topping application was added to both pre-emergent and post-emergent herbicides. The double-break tactic was highly successful, with the weed head numbers in the low-cost herbicide treatment reducing from 2399 to 35 heads/m^2 by the end of 2017. The effect of the double-break persisted after 2017, showing that it had degraded the weed seedbank significantly.

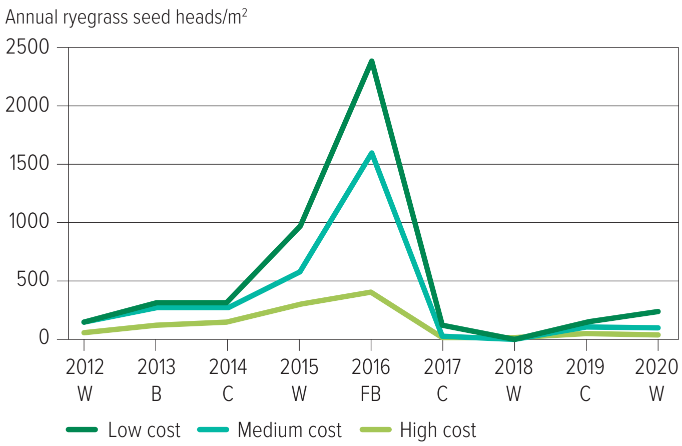
Herbicide cost, crop diversity and annual ryegrass control

Spending more money on herbicides consistently resulted in lower annual ryegrass numbers (Figure 11). Even though there was some increase in annual ryegrass numbers in the high-cost treatment, weed control was sufficient to prevent the blow-out that was seen in 2016 in the other two treatments.

However, no single herbicide strategy was able to prevent steady increases in annual ryegrass numbers from 2012 to 2015 and from 2018 to 2020, periods in which the majority of phases were cereals. This illustrates a significant feature of HRZ weed management. The long growing season challenges pre-emergent and post-emergent herbicides to provide season-long annual ryegrass control in cereals and, as a result, sufficient weeds survive, set seed and increase weed populations in subsequent years.

Therefore, weed seed-set is an important target for weed management. Important tactics to include are harvest weed seed control, cutting for hay and, as in the Lake Bolac trial, crop-topping in break crops. The Lake Bolac trial illustrates the value of diverse crop rotations paired with robust herbicide packages for an integrated weed management strategy that maintains low annual ryegrass numbers.

Figure 11: The mean effect of herbicide strategy on annual ryegrass seed heads/m^2 in a nine-year trial at Lake Bolac.



W is wheat, B is barley, C is canola, FB is faba beans.
There are significant differences in all years except 2017 (GRDC Code SFS1904-003).

Herbicides as a long-term investment

The average costs of the three herbicide strategies for the nine years were $39/ha/year, $56/ha/year and $85/ha/year (see Table A3 in the Appendix for a summary of the herbicides and costs in each year). Each increase in herbicide cost resulted in an increase in final grain income, which more than offset the extra cost of the herbicides (Table 3). This equates to an average increase of $179/ha/year in profitability for the most intensive strategy.

The differences in grain yields were statistically significant only in four of the nine years. This illustrates that the benefits of increased herbicide expense and weed control may not be captured in every year because the season has a greater effect on yield than weed pressure. Instead, the benefits of improved weed control accumulate over time, paying off given the right conditions. Investing in robust herbicide programs with diverse rotations, long-term, could be seen as an investment that is as important as individual tactics.

Table 3: The effect of three herbicide strategies (low, medium or high cost) on grain yield, cumulative grain income and cumulative net benefit in a long-term trial at Lake Bolac, Victoria (GRDC Code SFS1904-003).

Herbicide strategy	Grain yield t/ha#			Cumulative grain income* $/ha			Cumulative net benefit** $/ha	
	Low	Med	High	Low	Med	High	Med	High
2012 wheat	8.0 -	8.0 -	8.4 -	$2468	$2468	$2579	-$16	$77
2013 barley	7.9 -	8.1 -	8.3 -	$4554	$4609	$4759	$24	$137
2014 RT canola	1.7 b	1.8 a	1.9 a	$5490	$5641	$5848	$114	$282
2015 wheat	2.3 c	2.6 b	3.1 a	$6181	$6452	$6784	$229	$468
2016 faba beans	3.8 -	3.9 -	3.8 -	$7306	$7610	$7924	$257	$469
2017 TT canola	1.6 c	2.3 b	2.7 a	$8220	$8918	$9458	$630	$1058
2018 wheat	3.4 -	3.5 -	3.5 -	$9273	$9977	$10,520	$605	$1034
2019 TT canola	2.9 -	3.0 -	2.9 -	$10,908	$11,669	$12,156	$641	$982
2020 wheat	7.1 c	9.3 b	9.7 a	$13,094	$14,531	$15,125	$1288	$1613

*Based on long-term median grain price at the Geelong port.
**The difference in grain income from the low-cost strategy, less extra herbicide costs.
Different letters indicate a significant difference based on the LSD (P<0.05); '-' indicates "not significant" (P>0.05).

HARVEST WEED SEED CONTROL IN THE HRZ

Does it have a profitable fit?

Key messages

- Harvest weed seed control (HWSC) that eliminates 30 per cent of weed seeds is likely to be profitable if extra costs are less than $34/ha.
- Annual ryegrass seed shedding and head lodging, associated with late harvest dates, are the primary causes of missed weed seeds from HWSC. The most effective HWSC option, weed seed impact mills, will remove around 30 per cent of annual ryegrass seeds, but results will vary widely depending on seasonal conditions.
- HWSC efficacy could be increased in cereals by windrowing. Its efficacy is not increased by harvesting lower than 30cm above the ground.
- In the long-term, using HWSC that removes 30 per cent of weed seeds from an intensive cropping system will stop the steady growth in annual ryegrass numbers that typically occurs, and may cause a decline in weed numbers.
- HRZ growers should consider adding HWSC to their farming systems to play a supporting role in integrated weed management strategies. Reduced harvest speed is a major cost and business risk to consider, especially with weed seed impact mills.

Figure 12: A mature annual ryegrass seed head in a wheat crop. The efficacy of HWSC is reduced by the late harvest dates of the southern HRZ.

Photo: Paul Breust

Why consider HWSC in the southern HRZ?

Controlling the annual ryegrass population through tactics that target weed seed-set have been shown to be important to HRZ rotations (see the sections 'Stacking weed management tactics in practice' and 'Using rotations and stacked tactics'). However, crop-topping cannot be used on all crop types, is compromised by the staggered germination and maturity of annual ryegrass, and is vulnerable to herbicide resistance. HWSC can fill this gap as a mechanical tactic for reducing weed seed-set that can be applied to all crop types.

While HWSC had been proven to be an effective tactic in several regions of the Australian grainbelt, until recently less work had been done in cool, high-rainfall environments. In these environments, harvest begins later in the calendar year, especially for cereals, increasing the chance for annual ryegrass seed loss through shedding. Furthermore, high-yielding environments have greater crop biomass, which will cause weeds to set seeds higher above the ground, with greater stubble loads, which favours higher cut heights. This raises the question of whether the recommended cut height of 15cm with HWSC is appropriate. A project with GRDC investment conducted from 2015 to 2018 aimed to address this gap by validating the profitability, efficacy and practicality of integrating HWSC into southern HRZ cropping systems. Small-plot trials were used to test efficacy, on-farm trials were used to test practicality, and the data was pooled in a model called LUSO (Land-Use Sequence Optimiser) to assess profitability.

The profitability of HWSC

The benefits of HWSC should occur over a rotation as annual ryegrass populations are reduced. To assess these benefits, the model LUSO was re-parameterised using the findings from small-plot trials and on-farm trials.

The extra cost of using a weed seed impact mill (WSM) was calculated from an on-farm trial using a 2017 model of the integrated Harrington Seed Destructor (iHSD). Using this WSM increased engine load by 15 per cent, fuel use by 37 per cent and reduced harvest speed by 36 per cent. Together, these extra costs were $34/ha. Significant improvements in HWSC technology have occurred since 2017, so HWSC running costs are likely to be lower now.

When the cost of HWSC is compared with the extra income from grain yield in a wheat/barley/canola rotation over 12 years, the model predicts the system will break even at the assumed HWSC cost of $34/ha in a paddock with good herbicide control (95 per cent of weeds killed each year) (see Figure 13). However, the addition of HWSC will be highly beneficial in a paddock with compromised herbicide control (90 per cent of weeds killed). Therefore, HWSC must cost less than $34/ha in total costs to be profitable across varying levels of herbicide efficacy. Lower-cost options such as chaff lining are also predicted to be profitable even if they are less effective than weed seed impact mills (data not presented).

Figure 13: Cumulative income after 12 years of a simulated wheat/barley/canola rotation, with or without a weed seed impact mill (WSM) that removes 30 per cent of weed seeds at harvest, and with effective herbicide control (95% of weeds killed) or ineffective herbicide control (90% of weeds killed) (GRDC Code SFS1507-003 – Harvest weed seed control for the southern high-rainfall zone).

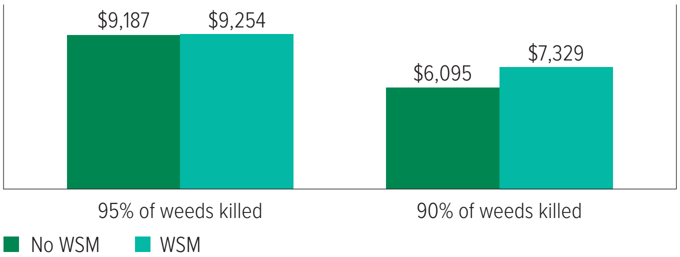


Figure 14: The proportion of total annual ryegrass weed seeds shed before harvest. The median value is 51% of seeds shed (GRDC Code SFS1507-003).

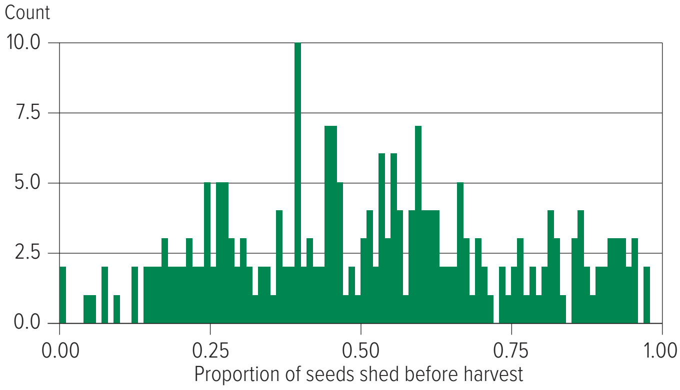
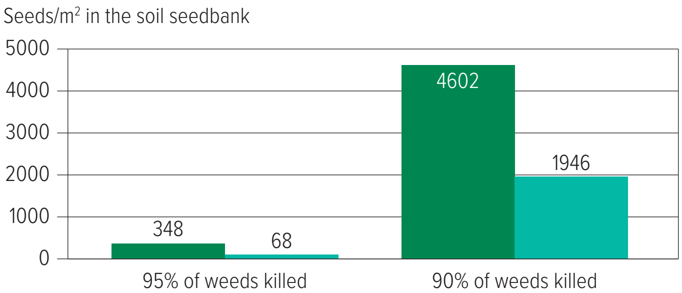


Figure 15: Final modelled annual ryegrass weed seedbank after 12 years of a wheat/barley/canola rotation, with or without a weed seed impact mill that removes 30% of weed seeds at harvest, and with effective herbicide control (95% of weeds killed) or ineffective herbicide control (90% of weeds killed) (GRDC Code SFS1507-003).



The efficacy of HWSC

HWSC is less effective in the HRZ, but it remains profitable because of the high financial returns from weed control (see 'Crop competition' section). The reduction in efficacy is due to significant weed seed shedding and weed head lodging before harvest. These factors were measured in small-plot trials that were harvested in the typical timeframe for cereals of December and January.

Weed seed shedding accounted for 50 per cent of missed weed seeds but was highly variable (see Figure 14). Weed head lodging, including lodged weeds and weed seed heads that had snapped off and fallen to the ground, accounted for another 20 per cent of missed weed seeds. Together, this means weed seed impact mills, the most effective option capable of eliminating 90 to 95 per cent of captured seeds, will typically remove 30 per cent of weed seeds from a cropping paddock. Cutting at 15cm instead of 30cm did not affect the number of seeds captured at harvest.

The model predicts that when effective weed control is achieved (95 per cent of weeds killed by herbicides), the addition of HWSC that removes 30 per cent of weed seeds leads to a slow reduction in the weed seedbank over 12 years of a wheat/barley/canola rotation (Figure 15). If weed control becomes less effective, HWSC can curtail rapid annual ryegrass population growth, but not stop it. HWSC is therefore likely to play a supporting role in an integrated weed management program in the HRZ.

Windrowing cereals can increase the efficacy of HWSC

In 2019, three on-farm demonstrations were conducted to assess the value of windrowing wheat and barley to increase annual ryegrass seed capture at harvest for HWSC. Sections of commercial standing wheat crops (approximately 0.25ha) at Wolseley and Conmurra, SA, were windrowed three weeks before the anticipated harvest date. At Wolseley, a chaff cart was used for HWSC, whereas at Conmurra a Seed Terminator weed seed impact mill was used. On the day of commercial harvest at each site, annual ryegrass populations were measured before harvest and after:

A. Direct harvest – 15cm cut height

B. Direct harvest – 5cm cut height (Wolseley only)

C. Windrowed – sampled after harvest from under the windrow and outside the row.

In each quadrat, the number of annual ryegrass plants was counted and the seeds were retained (including from fallen plant seed heads and surface chaff). The top 3cm of soil was also collected from the quadrats and ryegrass germinated on soil trays.

CASE STUDY:

2015 Integrated Harrington Seed Destructor, Don Robertson, Strathkellar, Victoria

Don Robertson runs a mixed farming business comprising 600ha cropping and 600ha sheep and cattle at Strathkellar, near Hamilton in Victoria. Don began to convert some land into cropping around 20 years ago, making him a relatively early adopter of a mixed farming system for the region.

However, after several years of cropping he began to encounter greater challenges with controlling annual ryegrass due to herbicide resistance. Like many in high-rainfall regions, he struggled to make narrow windrow burning achieve adequately hot temperatures under the typically cool and wet conditions. Windrow baling entailed too much work due to high stubble loads, with not enough improvement gained in weed control. Therefore, he decided to invest in an integrated Harrington Seed Destructor (iHSD) in 2015.

Don saw an immediate effect of the iHSD in his cropping paddocks. Typically, he had heavy annual ryegrass pressure where he ploughed an unburnt firebreak before burning his stubble; however, after using the iHSD he noticed far fewer weeds in those areas of the paddock. He also observed significant costs and risks with using the technology.

Having the built-in mill – an older model that is always running and cannot be switched on and off as required – meant he needed to wait an extra week to harvest after desiccating beans and canola because it could not handle any green material. In one season a foreign object ruined the mill and blew a hose, which caused a small fire. Fortunately, the damage was contained to the mill, which the manufacturer replaced. Perhaps the most significant impact on his business was that the iHSD reduced his harvest capacity from 40t/hour to 30t/hour.

However, the proof of the value of the iHSD came in the 2018 harvest via an unplanned demonstration. With a significant weather event on the horizon, Don was trying to finish as soon as possible. His neighbour, who owned a harvester similar to Don's but without the iHSD, was already finished at his property and came over to help Don with his last paddock.

As a result, one half of the paddock was harvested with the mill and one half was not. Don said the difference in weed pressure between the two halves was unmistakable, and that experience gave him a lot of confidence in the decision he had made. His success with annual ryegrass management is greatly improved and his agronomist has noticed the difference too.

Don is aware his business is able to absorb the extra harvest time required with a mill as his cropping area is relatively small. Nevertheless, being able to turn a weed seed impact mill on or off as required would make a big difference. He is interested in upgrading to a newer model in the future, but the price tag is an obstacle.

Figure 16: Annual ryegrass heads emerging above a wheat crop. Windrowing cereals might increase the efficacy of HWSC but cutting lower than 30cm in the HRZ will not.

Photo: Fleur Dolman

At Wolseley, ryegrass germination was reduced by 45 per cent by direct harvesting the crop at 15cm with a chaff cart (a reduction of 1568 plants/m^2) (Figure 17). Dropping the header cut height to 5cm further improved the capture of annual ryegrass seed, significantly reducing the population by another 45 per cent, to less than 400 plants/m^2. Harvesting this low comes with its own risks in stony ground, can slow operation speed and reduce the volume of fixed standing stubble; nonetheless, it may be a useful management tool in discrete weedy patches, particularly where annual ryegrass plants have lodged.

At Conmurra, direct harvesting with the Seed Terminator reduced the population by 30 per cent (560 plants/m^2) in comparison to the pre-harvest population (Figure 18). The two-week delay in harvesting at Conmurra (mid-January) may have resulted in greater seed shed and annual ryegrass lodging.

Windrowing and harvesting with a chaff cart reduced annual ryegrass germination by 70 per cent in comparison to the pre-harvest population at Wolseley (Figure 17). Windrowing in addition to using a Seed Terminator was even more effective at Conmurra, reducing it by 78 per cent, to 400 plants/m^2 (Figure 18). Between 60 per cent and 72 per cent of the annual ryegrass germinations in the windrowed paddock occurred under the windrow. In terms of wheat grain quality, windrowing reduced grain moisture at Conmurra slightly and had a small positive impact on protein at both sites.

Assessments were also conducted at Conmurra in a barley crop. The average ryegrass plant population at harvest was 44 plants/m^2, which was higher than in the wheat. Both direct harvesting and windrowing with a Seed Terminator effectively reduced subsequent annual ryegrass germination in barley, dropping the populations by 65 per cent and 79 per cent respectively.

At a cost of approximately $40/ha, the expense of windrowing warrants consideration as an additional tool that can be added to the annual ryegrass management kit. This is particularly true where herbicide-resistant annual ryegrass populations exist, providing there is the capacity to collect and/or destroy the harvested weed seed.

Key considerations for adopting HWSC in the HRZ

Given current knowledge and knowledge gaps related to HWSC in the HRZ, there are several things to consider before adopting a HWSC practice.

Consider a range of HWSC technologies for the best fit.

- There is a trade-off between cutting high to benefit harvest operations and cutting low to benefit sowing operations. In a series of research studies, HWSC efficacy was no different between 15cm and 30cm in the HRZ, so make a decision within this range. Visually observing the ryegrass in the paddock will aid this decision.
- Chaff lining and chaff decking (chaff tramlining) have a lower capital cost but may generate issues with concentrated rows of trash. The knowledge of the efficacy of these methods without follow-up management is limited in the HRZ. Having a few extra management options to implement with chaff-lining or chaff-decking in mind ahead of time, such as shroud spraying or grazing, are required to optimise their usefulness.
- Narrow windrow burning is often affected by cool and wet weather events in late summer, reducing its efficacy.

Acquire detailed information about the extra costs that will be incurred with a HWSC technology. The HWSC cost estimate tool can be accessed at: https://www.weedsmart.org.au/content/calculating-the-cost-of-hwsc-for-your-farm/

- The most important cost to quantify is harvest slowdown – it can be inconsequential with simple systems but up to a 30 per cent slowdown with older models of weed seed impact mills.
- There are cost-saving strategies that can be employed. For example, one could only engage a weed seed impact mill in annual ryegrass hotspots in a paddock. This will reduce costs and gain most of the benefits of weed seed elimination.
- If all extra costs are less than $34/ha then it is likely to be a profitable tool for weed control, especially if there are other challenges faced such as herbicide resistance.

Consider the timing of harvest operations and their risk.

- Mixed farming businesses that have fewer hectares of crop may be able to complete harvest more quickly than intensive cropping businesses.
- Due to the high level of annual ryegrass seed shedding, the earlier a cereal paddock is harvested (that is, in December rather than January) the more effective HWSC will be. However, HWSC was still effective in January in some years.
- Windrowing cereals could increase the efficacy of HWSC.

Figure 17: Annual ryegrass germination from plant and soil samples taken pre and post-harvest at Wolseley, where three harvest strategies were used with a chaff cart. Different letters indicate treatments that were significantly different.

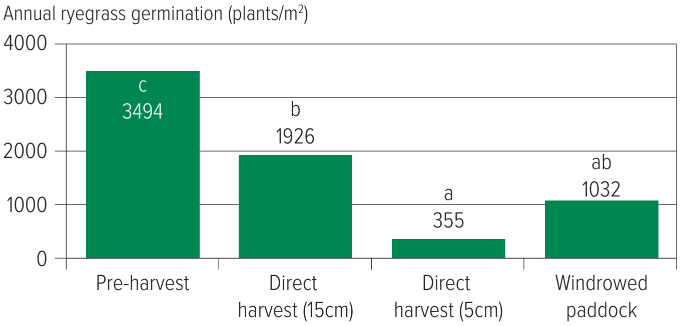
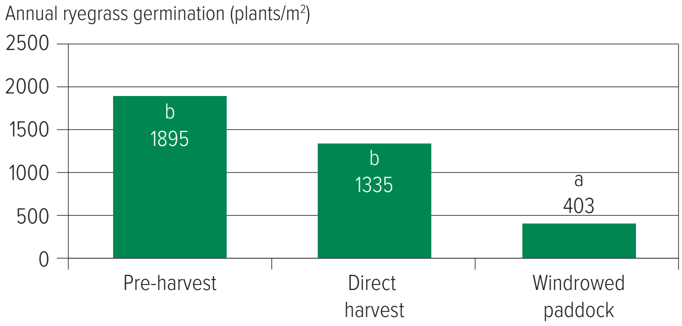


Figure 18: Annual ryegrass germination from plant and soil samples taken pre and post-harvest at Conmurra, where two harvest strategies were used with a Seed Terminator. Different letters indicate treatments that were significantly different.



CONCLUSION

Implications and next steps

Recent research and grower practice have provided several useful tactics for managing annual ryegrass in the HRZ. Double-break crops for two consecutive years allow good control of annual ryegrass seed production. Robust pre-emergent herbicide strategies can reduce early weed populations and increase crop yield. When coupled with other tactics, these can help maintain low annual ryegrass populations.

Crop-topping in non-cereal crops is effective at reducing annual ryegrass seed-set. Crop competition in cereals and canola can also help reduce seed-set. These are tools available to growers now to target the critical stage of seed-set.

There is evidence to suggest HWSC can contribute profitably to annual ryegrass management in the HRZ, yet it remains challenging as a practical option that is reliably effective in this unique environment. Further testing and development could make it a more viable option that growers feel comfortable adopting. Existing solutions include coupling HWSC with windrowing crops to increase its efficacy, and dropping the header cut height low only where bad patches of annual ryegrass occur to increase harvest speed and reduce extra costs.

Several new pre-emergent herbicide options have become available across crops in the rotation. These should allow better control of annual ryegrass in crops such as barley, and also take some pressure off the existing products. Used wisely, they could augment the current tools.

Even with the best of the current tools used, there will still be problems with years where late spring rains delay harvest and increase annual ryegrass seed-set. Growers need to take immediate action to reduce the weed seedbank when this happens.

APPENDIX: HERBICIDE TREATMENTS FROM LONG-TERM TRIALS

Table A1: Herbicide strategies used for annual ryegrass management in the low, medium and high-intensity management strategies for the Frances trial from 2014-2016.

Management strategy	RT canola 2014	Wheat 2015	Faba beans 2016
Low	Simazine 990g/ha pre Atrazine 990g/ha + clethodim 120g/ha post	Pyroxasulfone 100g/ha pre	Simazine 990g/ha + prosulfocarb 2000g/ha + S-metolachlor 300g/ha pre Clethodim 120g/ha + butroxydim 45g/ha post
Medium	Simazine 990g/ha pre Glyphosate 621g/ha early post Glyphosate 621g/ha + atrazine 990g/ha post	Pyroxasulfone 100g/ha + tri-allate 1000g/ha pre	Simazine 990g/ha + prosulfocarb 2000g/ha + S-metolachlor 300g/ha pre Clethodim 120g/ha + butroxydim 45g/ha post Glyphosate 270g/ha crop-top
High	Propyzamide 500g/ha + tri-allate 1000g/ha pre Glyphosate 621g/ha early post Glyphosate 621g/ha + atrazine 990g/ha post Glyphosate 1080g/ha crop-top	Pyroxasulfone 100g/ha pre Prosulfocarb 2000g/ha + S-metolachlor 300g/ha early post	Simazine 1000g/ha + propyzamide 1000g/ha pre Clethodim 120g/ha + butroxydim 45g/ha post Glyphosate 270g/ha crop-top

Pre = Pre-emergent
Post = Post-emergent

Table A2: Herbicide strategies used for annual ryegrass management in the low, medium and high-intensity management strategies (MS) for the Frances trial from 2019-2020.

<table>
<tr><th>Management strategy</th><th>MS 1</th><th>MS 2</th><th>MS 3</th><th>MS 4</th></tr>
<tr><td>2018 harvest (faba beans)</td><td>Glyphosate
480g/ha crop-top</td><td>Glyphosate
960g/ha crop-top</td><td>Glyphosate
480g/ha crop-top</td><td>Glyphosate
960g/ha crop-top</td></tr>
<tr><td rowspan="6">Wheat 2019</td><td colspan="4">Glyphosate 1080g/ha + oxyfluorfen 18g/ha knockdown</td></tr>
<tr><td colspan="2"></td><td colspan="2">Paraquat 270g/ha + diquat 230g/ha double-knock</td></tr>
<tr><td colspan="2">42cm row spacing</td><td colspan="2">21cm row spacing</td></tr>
<tr><td colspan="4">Pyroxasulfone 100g/ha + tri-allate 1000g/ha pre</td></tr>
<tr><td colspan="3"></td><td>Prosulfocarb 2000g/ha +
S-metolachlor 300g/ha early post</td></tr>
<tr><td colspan="2"></td><td colspan="2">Glyphosate 1350g/ha crop-top</td></tr>
<tr><td rowspan="3">Faba beans 2020</td><td colspan="4">Glyphosate 855g/ha + saflufenacil 16.8g/ha knockdown
Propyzamide 900g/ha + terbuthylazine 875g/ha pre</td></tr>
<tr><td colspan="2">Clethodim 120g/ha post</td><td colspan="2">Clethodim 120g/ha + butroxydim 45g/ha post</td></tr>
<tr><td>Glyphosate
495g/ha crop-top</td><td>Glyphosate
990g/ha crop-top</td><td>Glyphosate
95g/ha crop-top</td><td>Glyphosate
990g/ha crop-top</td></tr>
</table>

Pre = Pre-emergent
Post = Post-emergent

Table A3: A summary of the herbicide applications and total cost for each herbicide strategy used in a long-term trial at Lake Bolac, Victoria.

Year/crop	Low cost (Average $39/ha/yr)	Medium cost (Average $56/ha/yr)	High cost (Average $85/ha/yr)
2012 wheat	**$17.60/ha** Trifluralin 960g/ha IBS S-metolachlor 240g/ha IBS	**$33.17/ha** S-metolachlor + prosulfocarb 300 + 2000g/ha IBS	**$50.70/ha** Pyroxasulfone 100.3g/ha IBS Tri-allate 500g/ha IBS
2013 barley	**$17.60/ha** Trifluralin 960g/ha IBS S-metolachlor 240g/ha IBS	**$33.17/ha** S-metolachlor + prosulfocarb 300 + 2000g/ha IBS	**$53.07/ha** S-metolachlor + prosulfocarb 210 + 1400g/ha IBS S-metolachlor + prosulfocarb 90 + 600g/ha post
2014 RT canola	**$41.04/ha** Trifluralin 1440g/ha IBS Atrazine 990g/ha post Clethodim 118.8g/ha post	**$46.92/ha** Trifluralin 1440g/ha IBS Glyphosate 621g/ha post Glyphosate 621g/ha 2nd post Atrazine 990g/ha 2nd post	**$60.56/ha** Propyzamide 500g/ha IBS Glyphosate 621g/ha post Glyphosate 621g/ha 2nd post Atrazine 990g/ha 2nd post Glyphosate 1316g/ha crop-top
2015 wheat	**$34.90/ha** Trifluralin 1440g/ha IBS Tri-allate 500g/ha IBS S-metolachlor 240g/ha IBS	**$40.20/ha** Pyroxasulfone 100g/ha IBS	**$118.38/ha** Pyroxasulfone 100g/ha IBS Tri-allate 1000g/ha IBS S-metolachlor + prosulfocarb 300 + 2000g/ha post Weed seed impact mill at harvest
2016 faba beans	**$89.31/ha** Terbuthylazine 750g/ha IBS S-metolachlor + prosulfocarb 300 + 2000g/ha IBS Clethodim 120g/ha post Butroxydim 45g/ha post Uptake® 1% post	**$93.35/ha** Terbuthylazine 750g/ha IBS S-metolachlor + prosulfocarb 300 + 2000g/ha IBS Clethodim 120g/ha post Butroxydim 45g/ha post Uptake® 1% post Paraquat 200g/ha crop-top	**$90.42/ha** Terbuthylazine 750g/ha IBS Propyzamide 500g/ha IBS Clethodim 120g/ha post Butroxydim 45g/ha post Uptake® 1% post Paraquat 200g/ha crop-top
2017 TT canola	**$32.96/ha** Atrazine 990g/ha IBS Clethodim 119g/ha post Atrazine 990g/ha post Hasten™ 1% post Glyphosate 1316g/ha crop-top Liase 2% crop-top	**$54.74/ha** Propyzamide 500g/ha IBS Atrazine 990g/ha IBS Clethodim 119g/ha post Atrazine 990g/ha post Hasten™ 1% post Glyphosate 1316g/ha crop-top Liase 2% crop-top	**$64.79/ha** Propyzamide 500g/ha IBS Atrazine 990g/ha IBS Clethodim 57.6g/ha post Butroxydim 15g/ha post Uptake® 1% post Clethodim 119g/ha 2nd post Atrazine 990g/ha 2nd post Hasten™ 1% 2nd post Glyphosate 1316g/ha crop-top Liase 2% crop-top
2018 wheat	**$40.20/ha** Pyroxasulfone 100.3g/ha IBS	**$71.72/ha** Pyroxasulfone 100g/ha IBS Tri-allate 1500g/ha IBS	**$73.37/ha** Pyroxasulfone 100g/ha IBS S-metolachlor + prosulfocarb 300 + 2000g/ha post
2019 TT canola	**$33.27/ha** Atrazine 990g/ha IBS Atrazine 990g/ha post Clethodim 118.8g/ha post Liase 2L/ha post Hasten™ 1% post Glyphosate 658g/ha crop-top	**$50.29/ha** Atrazine 990g/ha IBS Propyzamide 500g/ha IBS Atrazine 990g/ha post Clethodim 90g/ha post Liase 2L/ha post Hasten™ 1% post Glyphosate 1316g/ha crop-top	**$85.30/ha** Napropamide 1000g/ha IBS Propyzamide 500g/ha IBS Atrazine 990g/ha post Clethodim 90g/ha post Butroxydim 20g/ha post Liase 2L/ha post Hasten™ 1% post Glyphosate 1927g/ha crop-top
2020 wheat	**$45.12/ha** Trifluralin 960g/ha IBS Tri-allate 1500g/ha IBS	**$73.37/ha** Pyroxasulfone 100g/ha IBS S-metolachlor + prosulfocarb 300 + 2000g/ha post	**$78.07/ha** Pyroxasulfone 100g/ha IBS Bixlozone 500g/ha IBS

Post = Post-emergent
IBS = Incorporation by sowing

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