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AUSTRALIAN HERBICIDE
RESISTANCE INITIATIVE

Harvest Weed Seed Control

Table of Contents

Harvest weed seed control in Australian grain cropping systems

Michael Walsh

Annual weed control through seed bank management

Targeting weed seeds at crop harvest is represents an opportunity to take pre-emptive action against the future interference from problematic weeds. Our most damaging crop weeds (annual ryegrass, wild radish, wild oats and brome grass) are annuals capable of annually establishing large viable seed banks. If freely allowed to produce seed that enter the seed bank, the inevitable consequences will be dramatic weed competition and an unsustainable cropping system. Fortunately seed bank decline is rapid for most of our problematic crop weed species. Without inputs a very large seed bank can be reduced to a very modest one in just a few years. A low weed seed bank allows easier and more effective weed control with a reduced risk for the development of herbicide resistance. Thus effective weed management in cropping systems is reliant on preventing viable seed entering the seed bank. Towards this, a number of systems have been developed over the past three decades that target the weed seed bearing chaff fraction during harvest.

Weed seed retention

The most troublesome annual weed species of Australian cropping produce mature seed upright plant structures at the time of commercial wheat crop harvest. Annual ryegrass, wild radish, wild oats and brome grass all retain high proportions (70%+) of total seed production above harvest cutting height (15cm) at the commencement of wheat crop harvest. This retained seed enters the harvester where it is processed and separated from the grain then subsequently exits the harvester, predominantly in the chaff fraction. The harvest residue spreading systems fitted to commercial harvesters ensure that this weed seed bearing chaff fraction is evenly redistributed across the crop field. Ironically, this process results in the persistence and expansion of weed populations. Thus the collection and management of the weed seed bearing chaff fraction is an opportunity to intercept this process towards reducing annual weed population densities. Towards this several harvest weed seed control systems (HWSC) have been developed with this aim.

Chaff carts

Chaff carts are towed behind headers during harvest with the aim of collecting the chaff fraction as it exits the harvester. The weed seed collection efficiency of several commercially operating harvesters with attached chaff carts has been evaluated by AHRI and found to collect 75 to 85% of annual ryegrass seeds, and 85 to 95% of wild radish seeds that entered the front of the header during the harvest operation (Walsh and Powles, 2007). Collected chaff must be managed to remove weed seeds from the cropping system. Typically this material is left in piles in the paddock to be burnt in the following autumn. In some instances though, chaff is removed from the paddock and used as a valuable source of feed for livestock.

In recent times there has been renewed interest in the use of chaff carts thanks to the new Lance Turner designed chaff conveyor system. Without the chaff processing by the old cross auger and blower system and the inclusion of some straw residue the resulting chaff heaps retain more air pockets resulting in a shorter burning time. Previously chaff heaps would potentially smoulder for two days whereas heaps formed with the new system will burn out completely in 6-8 hours.

Baling

An alternative to the in-situ burning or grazing of chaff is to bale all chaff and straw material as it exits the harvester. The Bale Direct System, developed by the Shield's family in Wongan Hills as a means for improving straw hay production, consists of a large square baler directly attached to the harvester that collects and bales all harvest residues. A significant secondary benefit is the collection and

removal of annual weed seeds. Studies by AHRI determined that approximately 95% of annual ryegrass seed entering the harvester was collected in the bales (Walsh and Powles, 2007). In addition to being an effective system for weed seed removal, the baled material can have a substantial economic value as a feed source. However, as with all baling systems, consideration must be given to nutrient removal from the farming system.

Narrow windrow burning

Establishing narrow windrows suitable for autumn burning is achieved by attaching chutes to the rear of the harvester to concentrate the straw and chaff residues as they exit the harvester (Walsh and Newman, 2007). This concentration of residue effectively increases the seed destruction potential of residue burning. With more fuel in these narrow windrows the residues burn hotter and longer than standing stubbles or even conventional windrows. Weed seed kill levels of 99% of both annual ryegrass and wild radish have been recorded from the burning of wheat, canola and lupin stubble windrows.

Because of the simplicity in their establishment narrow windrow burning systems are now being widely adopted across Australia. However, although relatively easy to establish it is difficult to effectively burn narrow windrows established across a large cropping program. These difficulties are mainly weather related with high temperatures poor wind conditions and rainfall all restricting burning efficacy. Additionally, burning narrow windrows in high yielding (>3 t/ha) wheat crop and barley in general is problematic due to the high residue levels. Effective narrow windrow burning is generally easier in canola and legume stubbles.

Chaff grinding

Processing of chaff sufficient to destroy any weed seeds present during the harvest operation represents the ideal system for large scale Australian conservation cropping systems. Rendering weed seeds non-viable as they exit the harvester removes the need to collect, handle and/or burn large volumes of chaff and straw residues. Due to the importance and potential industry benefits of this process there has been substantial interest in the development of an effective system. Darkan farmer Ray Harrington has developed the Harrington Seed Destructor (HSD), a cage mill based system attached to the harvester that processes chaff during harvest. Evaluation of this system under commercial harvest conditions by AHRI over a number of seasons has determined the HSD will destroy at least 95% of annual weed seed during harvest.

Summary

The practical implications of HWSC are a more resilient production system with some insurance against further resistance evolution. The combination of effective herbicides plus HWSC techniques has been shown to reduce and maintain weed populations at very low densities (e.g. < 1.0 plant m^{-2}) (Walsh et al. 2013). In cropping systems, low weed densities, regardless of their resistance status, allow flexibility in crop choice, seeding time and herbicide use. This flexibility provides producers with the capacity to readily adjust production practices in tune with seasonal and market considerations. Low weed densities in crop fields also play a critical role in sustaining herbicide resources for the ongoing control of crop-weeds despite their potential for herbicide resistance evolution.

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IWM is all about early seeding of a big crop
Peter Newman

It has taken me ten years to work out what integrated weed management is all about. Last year in the northern agricultural region of Western Australia it became very apparent that the growers with low weed seed banks were able to start dry sowing early without the need to wait for weed germination. These growers have very few livestock and are consequently sowing the entire farm to crop. This is where money can be made by investing in integrated weed management. To sow a large area of crop, early, the only way to succeed is to practice integrated weed management to achieve a very low weed seed bank. We have already proven quite convincingly, that herbicides alone are not capable of doing the job.

So how are they doing it?

One grower commented to me that in 2009 he crop topped a lupin crop that was quite clean and didn't really need crop topping. He said "this was really just like putting my knockdown on six months in advance". It is as simple as that. Growers that are experiencing the greatest success with IWM are simply taking every opportunity they can to stop weed seeds entering the seed bank.

It seems ironic that we would spend a growing season killing weeds with a number of herbicide applications only to go and spread the survivors evenly over the paddock at harvest.

Case studies

As part of my GRDC funded research and extension I have monitored thirty one focus paddocks. Growers have eroded their ryegrass seed banks from an average of 183 ryegrass / m^2 in 2001 to 6 ryegrass / m^2 in 2010 which equates to a 97% reduction over ten years. The growers in the northern agricultural region of WA are demonstrating that it is possible to maintain a continuous crop regime while eroding the seed bank of resistant ryegrass using a combination of herbicides and integrated weed management practices. Generally speaking, when growers put their mind to it they are successful at managing the seed bank of resistant weeds.

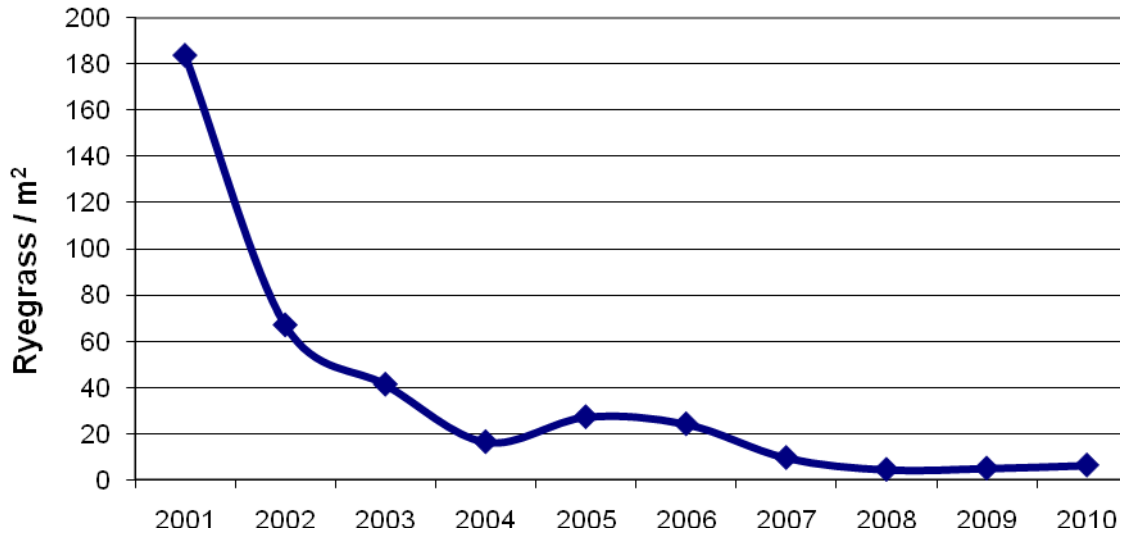

Figure 1. Average surviving ryegrass numbers across 31 focus paddocks counted each August. Ryegrass numbers decreased in all of the focus paddocks monitored over the eight year time frame. Approximately half of the focus paddocks had 0 ryegrass / m^2 in August 2010.

These focus paddocks clearly demonstrate that growers who choose to target the seed bank of resistant weeds, in most cases, win the battle. The majority of these growers have now had the experience of facing the problem of resistant weed blow outs, making changes to their farming system and then observing the benefits of these changes. They have been there and done that! They accept that managing resistant weeds will be an ongoing priority and they are generally optimistic that they will succeed when future challenges arise.

The success stories of these focus paddocks are too numerous to mention here. Some of the common management 'themes' that led to this outstanding result include high levels of trifluralin use pre sowing of all crops, high cereal crop seeding rates, high rates of Clethodim (Select®) in broadleaf crops, weed seed management at harvest by windrow burning or chaff cart, sacrificing of crops / pastures in weed blow-out situations, crop topping lupins to stop weed seed set, and generally high levels of crop hygiene.

Most of these growers comment that eight to ten years ago resistant weed management was at the top of the list of things to worry about. They now comment that they believe that resistant weeds will always be a challenge but they have other challenges ahead that outweigh resistant weeds.

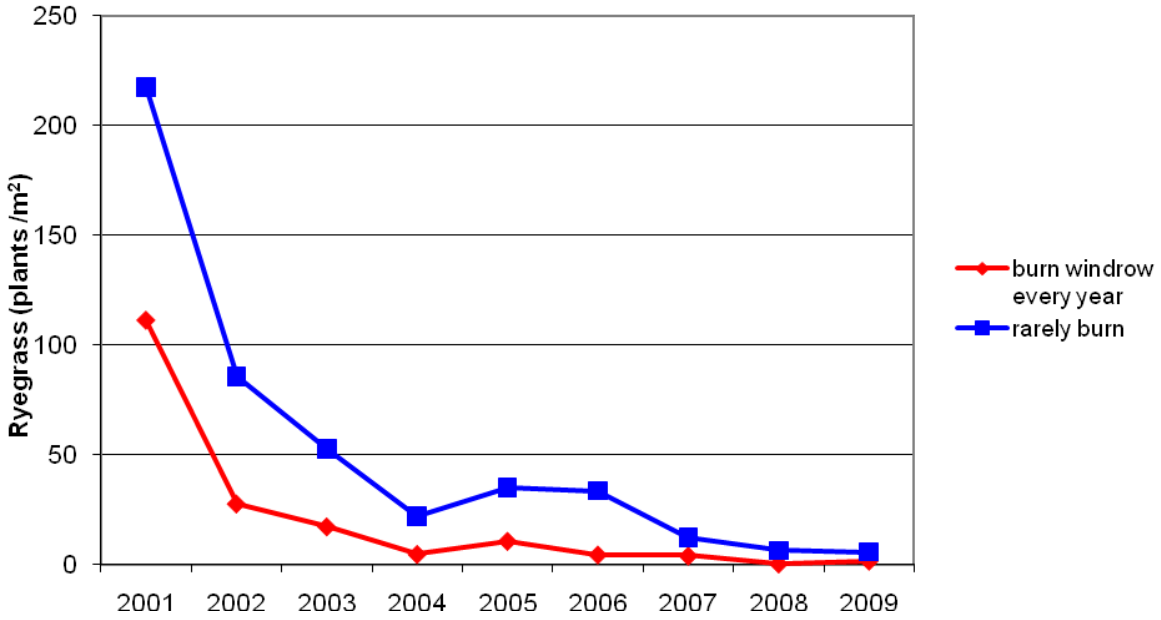

Figure 2. Comparison of focus paddocks where growers practice some form of harvest weed seed management most years (10 growers; windrow burning or chaff cart) compared to growers who rarely practice harvest weed seed management (21 growers).

The figure above clearly demonstrates the case for harvest weed seed management. Growers that practice harvest weed seed management such as windrow burning or chaff cart have quickly eroded their ryegrass seed bank to near zero after just three years of careful management. The growers who don't practice harvest weed seed management have also been very successful at eroding the ryegrass seed bank, however, this has largely been achieved through the use of selective herbicides. These growers generally have a background population of ryegrass every year over which selection pressure with selective herbicides is applied. As this ryegrass increases its resistance to trifluralin and clethodim (Select®), ryegrass numbers in these paddocks are likely to increase again. Growers with low ryegrass seed banks as a result of careful integrated weed management are likely to maintain low weed seed banks and extend the useful life of selective herbicides.

Farmer snapshot 1: Chaff Carts and Weed Management
Lance and Erin Turner

- Location: East Pingelly, Bullaring and East Corrigin
- Land area: 5800 ha
- Crop area: 5500 ha
- Annual Rainfall: 320–350 mm
- Growing season rainfall: 250–280 mm
- Soil type: East Pingelly - Duplex sand over clay; East Corrigin - red gravel soils
- pH: 4.5–4.7
- Yields: W – 2.6; B – 2.7; L – 1.4

In Australia, herbicide resistance is a major problem in cropping systems across the country, especially in annual ryegrass. Winning the battle against herbicide resistance requires good science, agronomy and engineering, along with well-trained people at all levels from high science, right through to dedicated farmers implementing a range of integrated weed control practices.

The Australian Herbicide Resistance Initiative's (AHRI) inaugural Resistance Champion (2013), Corrigin grain grower Lance Turner, is one such farmer.

After completing an AHRI Ryegrass Integrated Management (RIM) workshop in 1996, Lance realised the most economic choice to drive down weed numbers was to use a chaff cart at harvest. Towing a chaff cart for the past seven years in combination with a range of other tactics has been the key to Lance's ongoing success with weed control.

"Weeds dictate everything that we do.

"It's a whole systems approach. The chaff cart is not a silver bullet, but it's a pretty big linchpin in the whole system," Lance said.

Lance admits he initially had reservations about adopting a chaff cart due to the perception that it slows down harvest and because of the extra work required burning chaff dumps. However, he has developed a system that works well on his farm.

"We replaced the blower system with an elevator delivery system and found this improved chaff delivery into the cart, making the chaff cart much easier to use.

"The elevator system also leaves some straw material in the chaff fraction which increases oxygen levels. With the elevator system, the chaff dumps burn out in 8–12 hours, compared to 2–3 days with a blower system," he said.

With an integrated weed control approach, incorporating a range of herbicide and non-herbicide methods, around 95 per cent of his paddocks have low ryegrass and other weed numbers. This integrated approach enables Lance to reap the yield and profit benefits of seeding early each year, as well as maintaining a full range of weed control options.

Farmer snapshot 2: How to burn 10, 000 ha's of windrows
Andrew and wife Tracey, Rod and wife Sam, and father Charlie

- Location: Tenindewa and Eradu sand plain
- Land area: 12 500 ha
- Crop area: 10 000 ha
- Annual Rainfall: 336 mm
- Growing season rainfall: 260 mm
- Soil type: Mix of sandy loam and sand plain
- Yields: W - 2.2; L - 1.7; C - 1.3

The northern agricultural region of Western Australia is well known for its widespread herbicide resistant ryegrass and wild radish, and Mullewa grain growers Andrew and Rod Messina have developed a system to control these two notorious weeds.

The Messina's have taken a holistic approach to weed control, incorporating a mix of herbicide and non-herbicide practices into their farming system, including burning 10,000 ha of windrows (both wheat and broadleaf crops) each autumn. They have found that lighting up the windrow every 400 m allows the windrows to burn a lot quicker, whilst also maintaining their heat.

"There is no doubt that after two or three years of windrow burning we can see a notable difference in weed numbers for both ryegrass and wild radish - on some paddocks where we have been burning for years, paddocks were not sprayed for wild radish as numbers were so low.

"In our lupin rotation we have even left out metribuzin as wild radish is not the issue it was years ago. This is something we would not have contemplated before we began burning," Andrew said.

Weed seed kill levels of 99 per cent of both ryegrass and wild radish have been recorded from the burning of wheat, canola and lupin stubble windrows. Low weed numbers have given the Messina's the option of dry sowing.

"In this environment being able to dry sow is a major advantage; we need to get the crop in early and knowing that weed numbers are low from windrow burning gives us the confidence to go in and dry sow. We start seeding straight after Anzac Day and aim to finish before the first week in June."

Andrew believes their success with weed control is largely attributed to windrow burning, but that this tool alone will not solve a weed problem.

"There is no doubt that windrow burning has helped maintain our low weed numbers; however, we do not rely solely on this one tool. We take a holistic approach to our weed control and try to incorporate as many different tactics as possible, and this really is the key to successful and sustainable weed control."

Farmer snapshot 3: Evolution of the Harrington Seed Destructor
Ray and Tim Harrington

- Location: Darkan, WA
- Land area: 2000 ha
- Crop area: 1800 ha
- Annual Rainfall: 500 mm
- Growing season rainfall: 425 mm
- Soil type: Forest Gravels
- Yields: W – 3.33; B – 3.44; C – 1.8

Ray Harrington and his nephew Tim operate a farm in Darkan, Western Australia, approximately 250 km south of Perth, where he has been farming for 47 years. They have a 100% cropping enterprise with a wheat, barley and canola rotation.

The Harrington Seed Destructor (HSD) is a unique weed seed control system developed by Ray that smashes the chaff and weed seed fraction as it exits the harvester, destroying seed viability and returning the crushed fraction to the paddock.

“I tried everything from cooking, cremating and catching weed seeds and discovered that crushing the seed consistently gave the best results,” Ray said.

Unlike other weed seed harvest systems, there is no need for autumn burning and chaff and weed nutrients remain in the paddock.

AHRI research has shown that the HSD consistently destroys 95 per cent of annual ryegrass, wild radish, wild oats and brome grass seed present in the chaff fraction.

“We know those weeds will end up going through the Destructor so it’s like having a backup plan,” Ray said.

The encouraging field results warranted further development of the HSD. The GRDC awarded the commercial manufacturing license to de Bruin Engineering of Mount Gambier, South Australia in 2012.

University of South Australia have added further modifications. Their engineers have now built the first prototype of a mill that is mounted within the rear of the harvester to destroy weed seeds as they exit in the chaff fraction. This technology is still in the prototype stage, and the first indications are very exciting.

Ray stresses the HSD is not a silver bullet but it will make a difference to growers providing another tool to manage weeds and resistance.

“The HSD is no different to using a chaff cart - it’s the chaff cart evolved. You get the same end result but the HSD provides an easier way of getting there.”

How do you deal with your seedbank?
Any good ideas?
Put them to the test!

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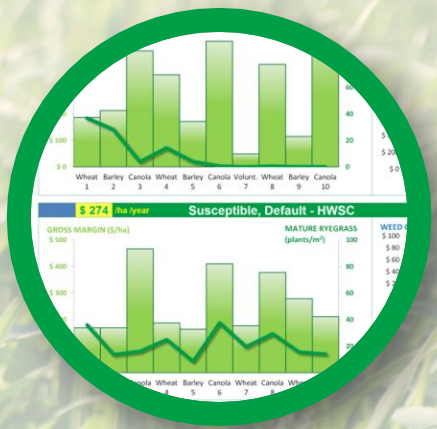

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10 WAYS YOU CAN WEED OUT HERBICIDE RESISTANCE

1. ACT NOW TO STOP WEED SEED SET.

- Destroy or capture weed seeds.
- Understand the biology of the weeds present.
- Remember – every successful WeedSmart practice can reduce the weed seedbank over time.
- Be strategic and committed – herbicide resistance management is not a one-year decision.
- Research and plan your WeedSmart strategy.
- You may have to sacrifice yield in the short term to manage resistance – be proactive.
- Find out what other growers are doing, visit www.weedsmart.org.

2. CAPTURE WEED SEEDS AT HARVEST.

- Options to consider:
  - Tow a chaff cart behind the header
  - Check out the new Harrington Seed Destructor
  - Create and burn narrow windrows
  - Produce hay where suitable
  - Funnel seed onto tramlines in CTF systems
- Use crop topping where suitable (southern and western grains region).
- Use a green or brown manure crop to achieve 100% weed control and build soil nitrogen levels.

3. ROTATE CROPS AND HERBICIDE MODES OF ACTION.

- Look for opportunities within crop rotations for weed control.
- Repeated application of effective herbicides with the same MOA is the single greatest risk factor for herbicide resistance evolution.
- Protect the existing herbicide resource.
- The discovery of new, effective herbicides is rare.
- There is no quick chemical fix on the horizon.
- Use breakcrops where suitable.
- High rainfall zone growers should plan carefully to reduce weed populations in the pasture phase prior to returning to the cropping.

4. TEST FOR RESISTANCE TO ESTABLISH A CLEAR PICTURE OF PADDOCK-BY-PADDOCK FARM STATUS.

- Sample weed seeds prior to harvest for resistance testing to determine availability of effective herbicide options.
- Use the "Quick Test" option to test emerged ryegrass plants after sowing to determine availability of effective herbicide options before applying in crop selective herbicides.
- Visit the WeedSmart website, www.weedsmart.org or www.ahri.uwa.edu.au for more information on herbicide resistance survey results
- Collaborate with researchers by collecting for surveys during the double knock program (northern region).

5. AIM FOR 100% CONTROL AND MONITOR EVERY SPRAY EVENT.

- Stop resistant weeds coming back into the farming system.
- Focus on management of survivors in fallows (northern grains region).
- Where herbicide failures occur, do not let the weeds seed. Consider cutting for hay or silage, fallowing or brown manuring the paddock.
- Patch spray areas of resistant weeds only if appropriate.

6. DON'T AUTOMATICALLY REACH FOR GLYPHOSATE.

- Use a diversified approach to weed management.
- Consider post-emergent herbicides where suitable.
- Consider strategic tillage.

7. NEVER CUT THE ON-LABEL HERBICIDE RATE AND CAREFULLY MANAGE SPRAY DRIFT AND RESIDUES.

- Use best management practice in spray application. For more information visit www.ahri.uwa.edu.au. GRDC has produced a series of fact sheets, available at www.grdc.com.au.
- Consider selective weed sprayers such as WeedSeeker or WeedIt.

8. PLANT CLEAN SEED INTO CLEAN PADDOCKS WITH CLEAN BORDERS.

- It is easier to control weeds before the crop is planted.
- Plant weed-free crop seed to prevent the introduction of new weeds and the spread of resistant weeds.
- A recent AHRI survey showed 73% of grower-saved crop seed was contaminated with weed seed.
- The density, diversity and fecundity of weeds is generally greatest along paddock borders and areas such as roadsides, channel banks and fencelines.

9. USE THE DOUBLE KNOCK TECHNIQUE.

- The double knock is the use of any combination of weed control that involves two sequential strategies; the second application is designed to control survivors of the first method of control used.
- Access GRDC research results at www.grdc.com.au or www.nga.org.au.

10. EMPLOY CROP COMPETITIVENESS TO COMBAT WEEDS.

- Consider narrow row spacing and seeding rates.
- Consider twin row seeding points.
- Use barley and varieties that tiller well.
- Use high density pastures as a rotation option.
- Consider brown manure crops.
- Rethink bare fallows (northern grain region).
- Select herbicide tolerant canola hybrids in crop rotations.

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