Inversion ploughing: Effects of long-term deep burial on weed seed reserves

Aik Cheam and **Siew Lee**, Department of Agriculture and Food, South Perth

KEY MESSAGES

- From the view point of weed management, inversion ploughing has a role in the control of grass weeds with short-term seed dormancy.
- However, when managing broadleaf weeds with long-term seed dormancy, one must be aware of the risk of prolonging their seedbank life. This could be a problem in herbicide resistance management after resistance has occurred.

BACKGROUND

Inversion ploughing or deep burial of weed seed using a mouldboard plough is a very effective method of decreasing seedling emergence. This is consistent with the results of many ecological studies which showed that weed seedling emergence is inversely related to the depth of seed burial and that maximum emergence is from shallow depths of around 1 cm for the majority of species. Small-seeded weeds can only emerge from shallow depths while large-seeded ones can germinate from greater depths if conditions are suitable, but rarely do they emerge from 15 cm or more. Therefore, the use of a mouldboard plough with a skimmer attached, that fully inverts the soil to bury weed seeds from on or near the surface to a depth of 15 cm or more, would result in a dramatic reduction of seedling emergence for the majority of weed species. However, data on the effects of inversion ploughing on the persistence and state of dormancy of weed seed reserves are currently not available.

AIMS

This paper presents data on the seedbank longevity of four major crop weeds in Western Australia, viz., annual ryegrass (*Lolium rigidum*), brome grass (*Bromus diandrus*), doublegee (*Emex australis*) and wild radish (*Raphanus raphanistrum*) at shallow and deep burial. The data were obtained in earlier studies and by presenting these data we aim to indicate the likely outcome of inversion ploughing in relation to seedbank depletion or persistence.

METHOD

Trials were initiated at Mt Barker, Northam, Chapman Valley, Mullewa and Mingenew in the early ‘80s and late ‘90s to examine the effects of soil depth on emergence and seed viability of a range of weed species which included annual ryegrass, brome grass, doublegee and wild radish. After burial of the newly-harvested seed at 0, 1, 5, 10 and 15 cm depths, there was no further soil disturbance. The buried seeds were recovered at yearly intervals and then extracted from the soil followed by germination in the laboratory to determine their viability. The ungerminated seeds were checked for viability by the tetrazolium chloride method and the number of viable seeds recovered for each treatment was then determined.

RESULTS AND DISCUSSION

Seed survival

Only the seed survival data at 0, 1 and 15 cm depths are presented in this paper (Table 1). Survival data of up to four years of burial were obtained for annual ryegrass, brome grass and doublegee at Mt Barker, Northam and Chapman Valley sites. With wild radish, data were obtained from Mullewa and Mingenew after five years of burial.

Table 1 **Seed survival of four major crop weeds in the WA wheatbelt after four[1] or five[2] years of shallow and deep burial. The data for wild radish are the mean over two sites but data for the other species are the mean over three sites**

Weed species	Viable seeds remaining (%) at three burial depths		
	0 cm	1 cm	15 cm
Annual ryegrass[1]	0.6	0.9	0
Brome grass[1]	0	0	0
Doublegee[1]	21.0	10.5	18.3
Wild radish[2]	0	0	33.0

It is apparent that the seeds of annual ryegrass and brome grass which have shorter dormancy than doublegee and wild radish were completely depleted after four years of burial at 15 cm depth. With doublegee, 18 per cnet of the seeds still survived after four years. Wild radish was the most persistent, with 33 per cent of the seeds surviving even after five years.

Dormancy state

The state of the recovered seeds was determined (Table 2) as part of the viability testing of the remaining seeds of doublegee and wild radish recovered from the 15 cm depth.

Table 2 **State of the remaining seeds of doublegee and wild radish after burial at 15 cm over a four- to five-year period**

Weed species	Enforced dormant (%)	Induced/innate dormant (%)	Field germinated and/or rotted (%)
Doublegee	3.1	15.2	81.7
Wild radish	29.0	4.0	67.0

The different states of dormancy of the recovered seeds would determine the number of viable seeds germinating when seeds are brought closer to the soil surface where conditions are suitable for germination. The presence of induced/innate dormancy in the recovered doublegee and wild radish seed means that soil inversion is likely to prolong the life span of the seed pool. Some farmers have complained that despite their efforts to eliminate seed return, wild radish still persisted after 10 years of intensive weed control. Results of a long-term trial reported elsewhere in this proceedings support this observation.

CONCLUSION

Disregarding the risk of wind erosion, inversion ploughing is a useful method of eliminating the seedbank of many of our grass weeds like annual ryegrass and brome grass which have short-term seed dormancy.

Although inversion ploughing has much success in preventing the emergence and eliminating the seed reserves of grass weeds, one should be aware that it can prolong the seedbank life of many broadleaf weeds including doublegee and wild radish which have seeds with long-term dormancy.

KEY WORDS

annual ryegrass, brome grass, doublegee, wild radish, inversion ploughing, seedbank

ACKNOWLEDGMENTS

Thanks to Zulkifli Li for technical assistance.

Paper reviewed by: JR Peirce

How long can wild radish seeds survive in the soil?

Aik Cheam and **Siew Lee**, Department of Agriculture and Food, South Perth

KEY MESSAGES

- Controlling seed set is of high priority when managing wild radish seedbank. Paying attention to the seedbank is important because farmers have been too pre-occupied with killing the emerged population.
- Wild radish seedbank decline is most rapid in the first 4–5 years and therefore the pressure on seed set control must be maintained during this initial period.
- Once the seedbank has reached a very low level, care should be taken to ensure no blowouts in seed production.
- Even after the initial decline in seedbank, remember that the remaining seeds can still give rise to low numbers of seedlings because they have a long life span that can last over 10 years.
- The larger the seedbank, the longer it takes for it to be eroded to an acceptable level.

BACKGROUND

'How long can wild radish seeds survive in the soil?' is one of the most frequently-asked questions. In a 20–year study of buried seeds in undisturbed soil, Chancellor (1986) claimed that there were still one to two seeds surviving after 20 years of burial. It is well known that wild radish seeds are preserved by burial and will germinate only after they are brought to the soil surface. Therefore, under cropping situations where there are vertical redistributions of the seeds in the soil by cultivation, one would expect the seedbank to have a shorter life-span. However, the lack of data under cropping situations has prompted the undertaking of a long-term experiment to monitor the depletion of the seedbank of wild radish under intensive weed management regimes under various rotations.

AIMS

The aim of this experiment is to establish the longevity of the seedbank of wild radish under complete or near-complete seed set control over a 10–year period. This population has been found to be resistant to atrazine (Group C) and diflufenican (Group F).

METHOD

Table 1 shows the crop and weed control treatments evaluated for the best and worst rotations.

Table 1 **Crop and weed control treatments evaluated in the best and worst rotations**

Year	Rotation	
	Best	Worst
1999 (Start)	Wheat (Buctril MA 1.4 L, Z13–Z30)	TT – Canola (Atrazine 2 L pre-em; 2 L post-em)
2000 (Year 1)	Wheat (Logran (IBS) 35 g)	Wheat (MCPA amine 500 mL + Ally 3.5 g + Glean 4 g)
2001 (Year 2)	Cadiz pasture (Mowing once)	Cadiz pasture (Green manuring with offset disc, glyphosate to kill survivors)
2002 (Year 3)	As in 2001	As in 2001
2003 (Year 4)	Wheat (Glean 5 g + MCPA LVE 500 mL)	Wheat (Affinity 60 g + MCPA amine 500 mL)
2004 (Year 5)	Wheat (Paragon 375 mL)	Wheat (Giant 0.6 L)
2005 (Year 6)	Cadiz pasture (Hay-freezing with glyphosate)	Cadiz pasture (Hay-freezing with glyphosate)
2006 (Year 7)	Wheat (Buctril MA 1.4 L)	Wheat (Glean 5 g + MCPA LVE 500 mL)
2007 (Year 8)	Wheat (Giant 0.6 L)	Wheat (Paragon 375 mL)
2008 (Year 9)	Wheat (Glean 5 g + MCPA LVE 500 mL)	Wheat (Buctril MA 1.4 L)

During the wheat phase, herbicides were used to control the wild radish population because of the availability of a good range of herbicides for controlling the population despite its resistance to Group C and Group F herbicides. Cadiz serradella was used in the pasture phase to exploit the use of non-selective herbicides and management practices, such as green manuring and slashing, to control the seed production of wild radish in spring. The trial was sited at the Avondale Research Station in Beverley, Western Australia, from 1999 to 2009.

During the first few years, the soil seedbanks of wild radish were monitored at yearly intervals. Using this approach, it was possible to determine population trends and annual rates of change for the various treatments. In later years however, when the seedbanks had reached a very low level, soil sampling was replaced by seedling emergence monitoring. This was because the collected soil samples no longer gave reliable estimates of seed numbers.

The results obtained over the past nine years are presented here.

RESULTS AND DISCUSSION

Control of wild radish

In 1999, the worst rotation occurred where canola was planted and wild radish survival was high (averaging 76%) because of the failure of atrazine. This confirmed the triazine resistance status of the population. In contrast, in the best rotation involving a wheat crop treated with Buctril MA, there was total kill of wild radish.

In 2000, the overall performance of the herbicides was poor because of the severe drought.

In 2001, survivors in the best rotation were due to regrowth after mowing.

From 2002 onwards, all the treatments were very effective, resulting in total kill of wild radish, so there were no fresh seed inputs (Table 2).

Table 2 **The presence(√) or absence (X) of total kill of wild radish following the respective weed control treatment for each year**

Rotation	Year									
	Start	1	2	3	4	5	6	7	8	9
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Best		X a	X c	√	√	√	√	√	√	√
Worst		X b	√	√	√	√	√	√	√	√

a Number of survivors averaged 22 plants/m^2.

b Number of survivors averaged 604 plants/m^2.

c Number of survivors averaged 17 plants/m^2.

Seedbanks

The main effect of not controlling wild radish in any one year was a rapid increase in the wild radish seedbank in the following year because of the massive seed production by the wild radish survivors. The initial seedbank was about 800 seeds/m^2 in 1999. At the start of the following season in 2000, in the worst rotation, the seedbank had reached 3,743 seeds/m^2. This was because of the failure to control wild radish in the preceding season due to wild radish being resistant to triazines. The survivors produced many seeds to recharge the seedbank. In contrast, in the best rotation the seedbank was reduced to 63 seeds/m^2 at the start of the second season because of the excellent control of wild radish by Buctril MA in the preceding season.

Seedling emergence

As evident from the results in Table 3, even after 9 years of intensive weed control, the best rotation still ended up with 1 plant/m^2, and the worst rotation 2 plants/m^2.

Table 3 **Wild radish density (plants/m^2) in the best and worst rotation over a 9–year period. Data referred to the emerged population before any control treatment**

Rotation	Year									
	Start	1	2	3	4	5	6	7	8	9
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Best	800 seeds m^{-2}	40	115	24	16	4	3	3	1	1
Worst		1858	1274	85	43	15	10	6	3	2

CONCLUSION

- Complete exhaustion of the seedbank is unlikely to occur in the short term because of the capacity of wild radish seeds to survive long periods in the soil as evident by the 1 to 2 plants/m^2 that emerged despite nearly 10 years of intensive control. Surprisingly, there was not much difference in the size of the emerged populations despite the large differences in the size of the seedbanks in the initial years.
- Seed set control is the most important operation when attempting to manage a wild radish seedbank. A single break year of very little or no seed set will have a dramatic impact on the seedbank enrichment process.
- Planting wheat has a very significant impact in controlling wild radish. This is because of the availability of a good range of effective herbicides, supplemented by the high competitiveness of cereals.
- The introduction of a pasture phase has a significant impact in reducing the wild radish seedbank as well. This is because it allows the use of green or brown manuring or mechanical slashing to control the seed production of wild radish in spring.

KEY WORDS

wild radish, seeds, survive, soil

ACKNOWLEDGMENTS

Thanks to Zulkifli Li for technical assistance.

Paper reviewed by: JR Peirce

An economic comparison of IWM tools

Rob Grima, Department of Agriculture and Food, Western Australia

KEY MESSAGES

- Most weed control practices analysed required similar yield increases to justify their adoption.
- The adoption of an IWM tool to allow 100 per cent crop is determined by its ability to provide adequate weed control when used strategically.
- Various barriers to adoption exist for each IWM tool.
- An IWM tools ability to allow 100 per cent crop is determined by its biological performance, not its cost!

AIMS

To determine what yield response is required to justify the increased costs from adopting one of a range of integrated weed management (IWM) tools, and to determine which tools economically allow increased cropping for medium rainfall farms in the northern agricultural region

METHOD

Standard farms

The computer simulation model STEP (Simulated Transition Economic Model) was used to produce six standard farms that represented the soil type and production differences that occur across the NAR medium rainfall zone. In consultation with growers, consultants and researchers, the farms were developed to understand the influence of various levels of cropping per cent on profit. It was determined that profit was optimised in all farms when at 70–80 per cent cropping. Increased cropping resulted in reduced average yields for various reasons. One reason was increased competition from weeds due to reduced cultural weed control and less timely application of herbicides. Hence if IWM tools can be added to these farms they must overcome the increased weed burden sufficiently to allow 100 per cent crop.

IWM tools

Each IWM tool was evaluated for their cost, replacement frequency and their likely ability to control weeds sufficiently when used strategically. The costs were calculated by various means. Capital costs were determined as closely as possible according to commercial prices. Variable costs were calculated in accordance with growers' anecdotal evidence. Each IWM tool was then individually added into each standard farm, and it was then determined what yield increase would provide an annual profit similar to that achieved previously in the optimal enterprise mix. Each tool was assessed over a 20 year time frame. There are vast differences in replacement times between each IWM tool, and this time frame is sufficient to make comparisons.

RESULTS

Differences exist between the standard farms, and hence the yield improvements required to justify adoption of any IWM tool. Most red soiled farms have no viable pulse option in their rotation. Hence 100 per cent cropping requires a significant level of cereals. Root and leaf diseases increase the average yield losses for these rotations, along with increased weed burden. Adoption of an IWM tool may overcome the weed burden but not other issues. Hence farms with red soils have higher required yield improvements for almost all tools (Table 1).

With the exception of autumn tickle, all tools assessed had similar yield increase requirements to justify adoption (Table 1). This is despite vastly different set up costs, replacement frequencies and variable costs. Therefore, the ability of an IWM tool to allow 100 per cent cropping is completely dependent on its ability to biologically control weeds sufficiently.

Table 1 **The yield increase required (%) to justify adoption of a range of IWM tools**

IWM tool	Yellow sand high	Coastal Mix high	Yellow sand Moderate	Coastal mix moderate	Red dirt and sand	Red dirt
Inversion ploughing	2.5	3	5.5	5.5	13	16
Fallow	0.5	2.5	2	4	3	5
Autumn tickle	7	8.5	11	12	15	21
↑ Seeding rate	3.5	3.5	7	6	13	17
↓ Row spacing	3.5	3.5	6.5	6	13.5	16.5
New herbicide	3	3	6	5.5	-	-
Shielded sprayer	3.5	4.5	7	8	-	-
WeedSeeker	2.5	2.5	5	5	12.5	16
Crop topping	3	3	6	6.5	12	-
Crop sacrificing	3.5	3.5	6	6	13.5	16.5
Harvest straw baler	3	3	5	6	10	10
Harvest chaff cart	3	3	6.5	5.5	13	16
Windrow burning	2	2	4.5	4.5	12	14.5

Large differences in set up and variable costs exist between each tool (Table 2).

Table 2 **Set up costs, variable costs and other issues for each IWM tool**

IWM tool	Set up costs ($)	Replacement frequency	Variable costs ($/ha)	Notes
Inversion plough	$88,000	20 years	$50 approx.	5% of farm done annually
Fallow	-	-	24	10% of the farm done annually
Autumn tickle	-	-	$50 approx.	2 week delayed sowing
↑ Seeding rate	-	-	$12.50	From 50 to 100 kg/ha
↓ Row spacing	$120,000	10 years	$5	Extra tines and more tractor power
New herbicide*	-	-	$25–50	
Shielded sprayer	$40,000	10 years	$15	Half of lupin programme done every year, also increased tractor use increases replacement frequency
WeedSeeker	$120,000	20 years	$5	50% of crop sprayed annually
Crop topping	-	-	$13	50% of lupin area sprayed annually
Crop sacrificing	-	-	$15	< 2% weediest part of farm annually
Harvest straw baler	$120,000	6–7 years	$10 + $2	Extra harvest plus bale removal costs
Harvest chaff cart	$40,000	10 years	$10 + $2.50	Extra harvest plus burning costs
Windrow burning	$500	6–7 years	$2.50	

* This is a hypothetical new herbicide and not specific to any product.

CONCLUSION

It has been demonstrated that a number of IWM tools are known to reduce weed seed banks in future growing seasons. Tools that collect weed seeds at harvest are most likely to succeed, but inversion ploughing, a WeedSeeker®, and a shielded sprayer also show promise.

Strategic IWM tools

Burning stubbles (complete paddock) has always been a part of WA agriculture, but burning windrows is becoming the preferred technique. While the erosion threat still exists, the risk is lower when windrows are burnt than whole paddocks. It is inexpensive when done in the right conditions and can also be less time consuming than burning chaff heaps. Many growers successfully utilise this tool in 100 per cent cropping systems and continue to erode the seed bank (Newman 2009).

Harvest baling has been successfully implemented on at least one farm in WA. It has the added bonus of producing another saleable item and increasing whole farm profit. But capital cost over $100K to setup the baler would scare off most growers. There is also a risk that an oversupply of straw bales may reduce the unit price if widespread adoption occurred. Chaff carts again have proven their worth in 100 per cent cropping systems. The slow harvest issues and labour intensive burning exercise have and will continue to diminish the potential of this excellent product. Many growers were hopeful, and still are, of a seed destroying implement that is utilised during the harvest process. They would prefer to use this than rely on burning any material. The introduction of such an implement may be readily adopted if it became commercially available.

Shielded sprayers have also been tested on WA farms but are time consuming and costly to run. Experience also suggests two sprays are required, making this option financially unattractive. If a system allowing only one pass was to be developed, this option would appear more attractive.

Inversion ploughing is still in the development phase, but early indications for weed control purposes are excellent. Other benefits may also exist such as reducing water repellency. The burial of weed seeds at depth severely diminishes their capacity to germinate in crop. The WeedSeeker® may possibly be able to pick flowering radish against a green crop. Hence if radish is your main weed then this may be an excellent option. It is expensive to set up, but herbicide usage should decrease upon adoption, and summer weed spray costs will also be reduced. Both of these tools need more development, but they show enormous promise.

Tactical IWM tools

Tools such as crop topping or sacrificing can work extremely well when used tactically in weed blowout situations. These tend to not have high set up costs and can be adopted readily. Many growers already successfully utilise them. Crop topping in particular is an excellent option when optimal weed and crop stage present themselves. This does not occur for every crop every year, and if used as such will have significant yield losses or reduced weed control. Similarly crop sacrificing can be very effective on small weedy areas where low yields are likely. Weeds however tend to be distributed across large areas with moderate yield potential making this tool unsuitable strategically.

Increasing seeding rate is an easy option for many growers and has been shown to reduce weed seed production (Minkey 2000). Decreasing row spacing is unfavourable as perceived stubble handling problems and increased horsepower requirements are not popular. It is interesting that these costs in the long term are not large and are similar to increasing seeding rate from 50 to 100 kg/ha.

Whilst a fallow system is strictly not 100 per cent crop, this tool fits into a crop only enterprise. The results in Table 1 are for a farm where each paddock is fallowed every 10 years (10% fallowed annually). It is difficult to know if the weed control will be sufficient for benefits during the long period between fallows. Required yields for fallowing 20 per cent of the farm (1 in 5 years) are increased significantly. Fallowing alone may not be a viable option.

Many IWM options exist for growers to reduce their weed populations. Their costs mean yield increases are required to economically justify their adoption. Weed seed collection at harvest has proven to biologically allow 100 per cent crop in some systems. These options are no more costly than others. Growers wishing to increase their cropping % should first get their harvest systems right to maximise their chance of success. Other options can also be used tactically to manage weeds and increase growers' ability to crop a higher percentage of their farm.

KEY WORDS

Integrated Weed Management (IWM) tool, yield reduction, optimal profit

REFERENCES

Newman P (2009) Eight years of IWM smashes ryegrass seedbanks by 98 per cent over 31 focus paddocks. *Proceedings of the 'Crop Updates 2009'*. Perth, February 2009.

Minkey D (2000) Effect of seeding density, row spacing and Trifluralin on the competitive ability of Annual Ryegrass in a minimum tillage system. *Proceedings of the 'Crop Updates 2000'*. Perth, February 2000.

ACKNOWLEDGMENTS

Funding bodies NLP, MIG and NACC, and Sam Harburg, Peter Newman, Cameron Weeks and Caroline Peek.

Project No.: NLP 053064–07MIG

Paper reviewed by: Andrew Blake

Emerging weeds in changing farming systems

Dr Abul Hashem, Department of Agriculture and Food, Western Australia, Northam

KEY MESSAGES

- A collaborative project funded by GRDC will determine the emerging weeds and their potential threats within southern and western regions of the Australian grain belt.
- This project will also investigate the biology of emerging weeds, develop a package for the management of these weeds and communicate information for adoption by growers.

AIMS

The Department of Agriculture and Food, Western Australia (DAFWA) and Curtin University have been funded by GRDC to undertake a project on emerging weeds in changing farming systems in collaboration with the University of Adelaide (UA). The project started on 1 July 2008 and ends on 30 June 2011.

The following scientists and technical staff are participating in this project:

Western Region: (DAFWA and Curtin): Dr Abul Hashem, Dr Pippa Michael (Curtin), Dr Roger Mandel (Curtin), Dr Catherine Borger, Dr Sally Peltzer, Ms Barbara Sage, Ms Vanessa Stewart and Mr Glen Riethmuller.

Southern Region (UA): Dr Gurjeet Gill, Dr Chris Preston and Mr Ben Fleet.

The aims of the project are:

1. Develop survey strategies and identify emerging weed threats to cropping in the southern and western regions of Australia.
2. Determine seed bank biology and population dynamics of emerging weed threats under changing farming practices.
3. Undertake research to develop effective management practices for the control of these emerging weed threats.
4. Development of management packages and their adoption by the growers in southern and western regions.

METHOD

The proposed project will undertake research on the: (1) identification of emerging weeds in southern and western regions; (2) factors contributing to their increasing abundance; and (3) developing and promoting adoption of practices for their effective management.

Survey on emerging weed threats

This project is currently underway and involves a coordinated field and postal survey of weeds of cropping paddocks in order to identify emerging weed threats in each region. A comprehensive physical field survey on the emerging weeds within different regions of the WA wheatbelt from Geraldton to Esperance and Albany was completed in spring 2008. Approximately 60 per cent of sites surveyed in a previous DAFWA weeds survey in 1997 under the CRC Australian Weed Management were resurveyed in 2008.

A postal survey to determine the weed threat based on famers' experience and observation is near completion within WA and is being coordinated by Curtin University researchers.

Identify factors responsible for increasing abundance of emerging weeds

On-farm populations of selected weed species were collected during spring 2008 and investigations on the seed dormancy and germination behaviour are in progress under laboratory conditions. Field studies will be undertaken to determine weed behaviour through studies on loss of seed dormancy and recruitment behaviour of emerging weeds.

Development of management packages for emerging weed threats

Field studies will also be undertaken during 2009 and 2010 seasons to determine the effectiveness of crop rotations and different chemical and non-chemical weed control options for the management of selected emerging weed species.

CONCLUSION

Findings from the weeds surveys and laboratory and field research will be communicated at field days, crop updates and other rural media for the adoption by growers.

KEY WORDS

emerging weeds, survey, dormancy, seed bank, control options

ACKNOWLEDGMENTS

We sincerely acknowledge the kind assistance of Department of Agriculture and Food, Western Australia staff including Mr Peter Newman, Mr Aaron Middleton, Mr Dave Nicholson, Mr Paul Matson, Ms Alex Douglas, Mr Damian Shepherd (CRIS), Mr Joshua Smith (CRIS), Mr Mario D'Antuono, AgMemo and E-weed editors, and WANTFA staff in the conduction of the field and postal surveys.

Project No.: UA00105

Paper reviewed by: Dr Pippa Michael

Eight years of IWM smashes ryegrass seed banks by 98 per cent over 31 focus paddocks

Peter Newman, Glenn Adam and **Trevor Bell**, Department of Agriculture and Food, Western Australia, Geraldton

KEY MESSAGES

Growers have eroded their ryegrass seed banks from an average of 183 ryegrass/m^2 in 2001 to 4 ryegrass/m^2 in 2008 which equates to a 98 per cent reduction over eight years of weed management across 31 focus paddocks. 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.

AIMS

To improve communication of IWM practices between growers and to evaluate the effectiveness of 'real life' IWM practices.

METHOD

At the beginning of a five year, GRDC funded project, four small grower groups were formed to participate in IWM research and extension. These growers nominated a focus paddock that was monitored throughout this five year project. Ongoing funding from GRDC has allowed for these paddocks to continue to be monitored for an additional three years.

Over the past eight years, growers recorded their weed management and weeds were counted by technicians Glenn Adam and Trevor Bell each August to determine the number of surviving weeds. Growers were then interviewed individually to discuss the weed management of their focus paddock. A booklet documenting these paddocks along with the growers 'stories' was printed in 2006 and will be updated in 2009.

RESULTS

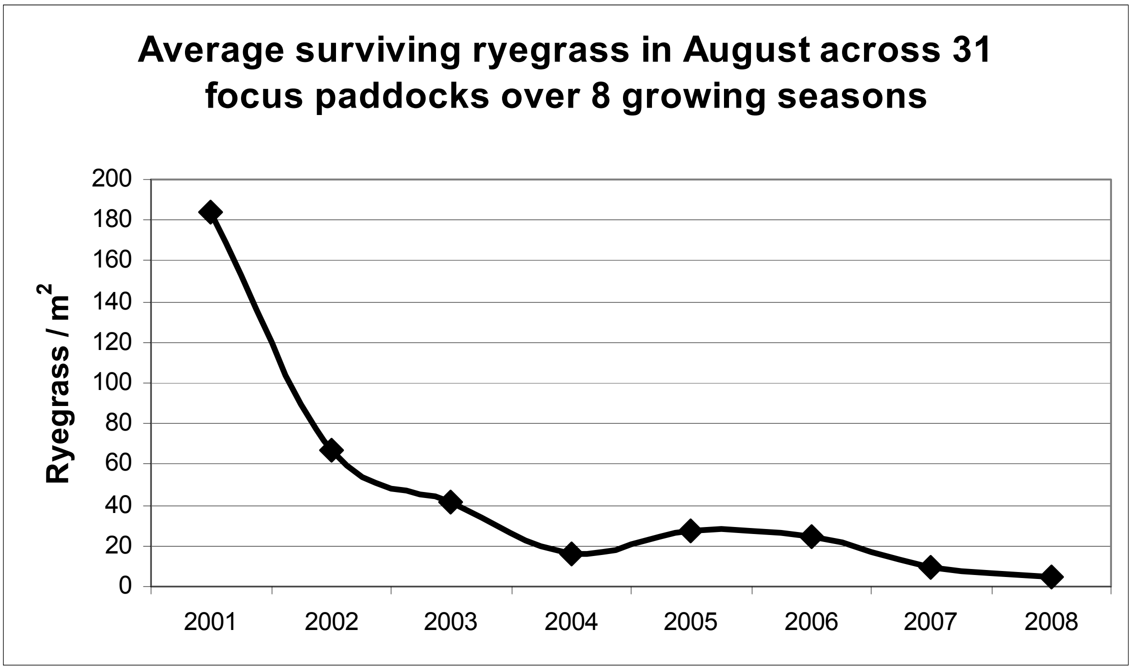

Figure 1 Average surviving ryegrass numbers across 31 focus paddocks counted each August.

On average, ryegrass numbers decreased by 98 per cent in the 31 focus paddocks over eight years of monitoring. Focus paddocks averaged 183 ryegrass/m^2 in 2001 and averaged 4 ryegrass/m^2 in 2008. 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 2008.

CONCLUSION

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, and generally high levels of crop hygiene. Participating growers are currently being interviewed to document their ‘stories’ of how this level of weed management was achieved. These stories and individual focus paddock data will be updated and printed in a booklet for distribution by June 2009.

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. Unfortunately human nature dictates that people must learn the hard way from their own experiences. Consequently, we still have many years ahead of growers experiencing the hardships of resistant weed management before they turn the corner and get on top of the problem. Ongoing communication throughout the state will be enhanced to assist growers who are at the early stages of resistant weed management.

Previous extension messages have largely focused on delaying the onset of herbicide resistance. This message may still be worthwhile for rare genes such as glyphosate resistance. However, in my opinion, these focus paddocks demonstrate the main priority of future extension should be managing resistant weeds rather than prevention.

Recent trends in the Northern Agricultural region of WA have seen two of the driest years on record (2006 and 2007) followed by a record grain harvest in 2008. The dry years led to as much as 80 per cent of the livestock leaving the region and many growers are commenting that they a reluctant to bring them back. Continuous cropping has become the norm, the majority of which has been wheat. Many paddocks were set up for wheat in 2008 after failed crops/fallowed paddocks in the dry years. Trifluralin use has increased and many growers now apply trifluralin to problem paddocks every year. New herbicides (some of novel mode of action) for the control of ryegrass and wild radish are now appearing on the Australian market as well as the growing of GM (Roundup Ready®) Canola. Wild radish resistance to group B and I herbicides has continued to increase in recent years and a range of new herbicides/brews are being applied at additional cost to the grower.

KEY WORDS

annual ryegrass, wild radish, focus paddock, herbicide resistance

ACKNOWLEDGMENTS

Many thanks to Glenn Adam and Trevor Bell for collating the data, and counting many weeds. Many thanks also to the participating growers and to GRDC for financial support.

Project No.: DAW0123

Paper reviewed by: Andrew Blake

Mouldboard plough—the answer to all of the problems with sandplain farming!

Peter Newman and **Steve Davies,** Department of Agriculture and Food, Western Australia

KEY MESSAGES

Non-wetting soil, herbicide resistant weeds, and sub-soil acidity are major limiting factors to cropping of sandplain soils in the Northern Agricultural Region (NAR) of WA. All of these limiting factors can take several years and a lot of money to correct. A one-off inversion of sandy soil with a mouldboard plough (fitted with skimmers) to a depth of 25 to 30 cm can fix all of these problems in one day! While this is a little facetious, there is a considerable amount of truth in this statement.

METHOD

These trials are all large scale demonstration trials in the Mingenew area that were seeded and harvested with grower machinery (with the exception of Prestons which is a small plot trial). Mouldboard ploughing treatments were conducted either in 2007 or 2008. Some of these yield results are from cover crops sown directly into mouldboard treatments while others are crops sown into mouldboard treatments from the previous year. Mouldboard ploughing was conducted with a three board Kverneland plough (owned by DAFWA) fitted with skimmers to a depth of 20 to 25 cm at a speed of approximately 4 to 5 kph. The Cosgrove site was ploughed in 2007 with a five board plough (owned by the Stokes family) fitted with skimmers working to a depth of 30 cm at approximately 10 kph. The soil was tested for non-wetting characteristics in the laboratory using both the water droplet penetration test and the molarity of ethanol droplet (MED) test (King 1981) which are standard and repeatable laboratory tests.

RESULTS

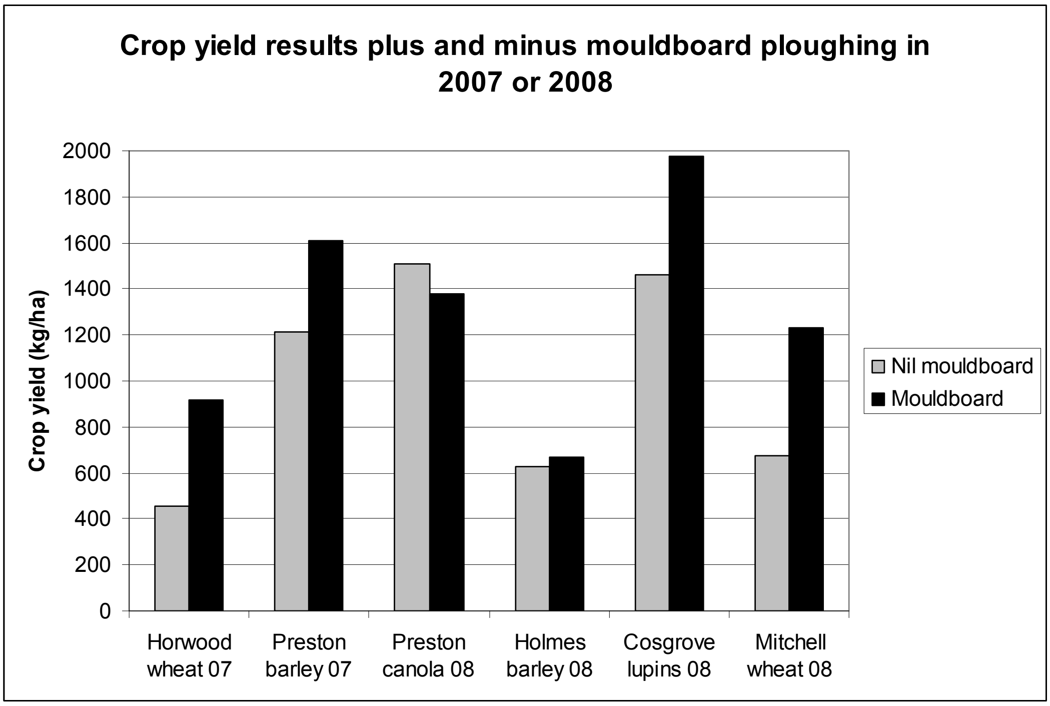

Figure 1 Crop yield (kg/ha) of Nil Mouldboard compared to Mouldboard treatment at a range of sites in 2007 or 2008.

Four of the six sites had significantly increased yield as a result of the mouldboard ploughing treatment. Canola establishment on mouldboard plots at the Preston site in 2008 was extremely poor as a result of the seeding machinery sinking in too deep on the mouldboard plots. Barley at the Holmes site was a cover crop sown on 5 June. This crop established well but did not cope well with dry conditions in August 2008. On average over all the trails and trial years there was a 41 per cent yield response to mouldboard ploughing.

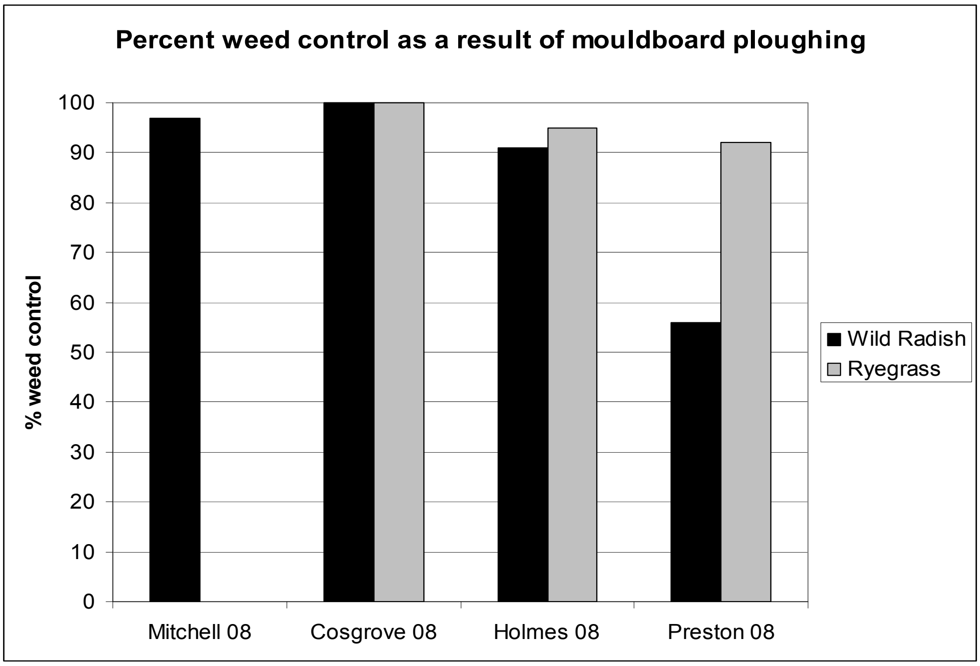

Figure 2 Per cent weed control as a result of mouldboard ploughing treatment at a range of sites.

Ninety to 100 per cent weed control was achieved at these four sites with the exception of wild radish at the Preston site. Some wild radish set seed at the Preston site in 2007 which has caused this poor result. Weeds were not measured at other sites but will be measured in the future.

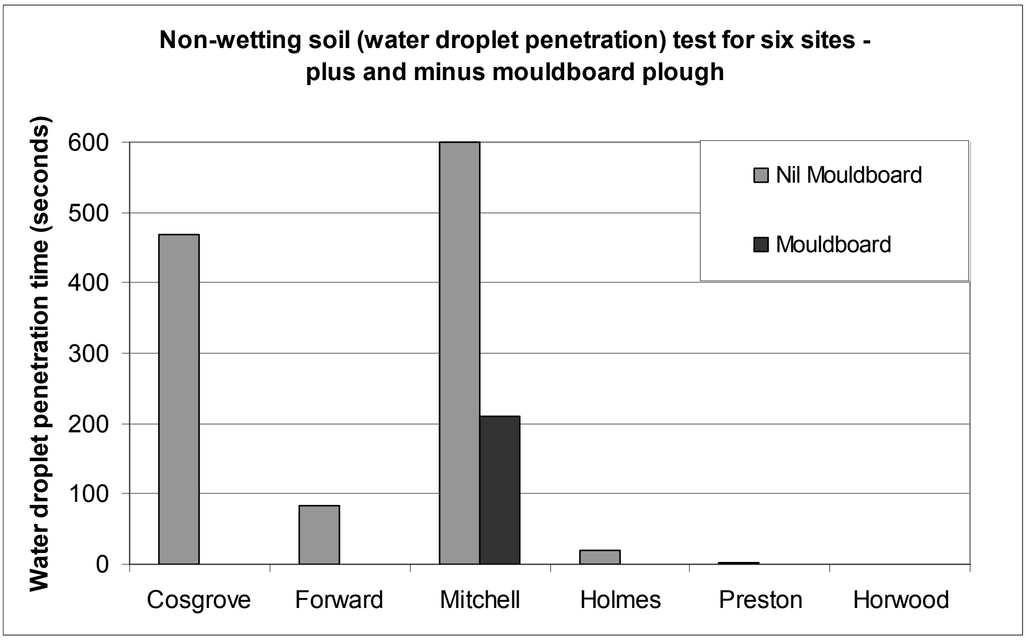

Figure 3 Water droplet penetration time (seconds) as measured under laboratory conditions for six sites plus and minus mouldboard ploughing.

The tests for non-wetting soil characteristics confirmed severe repellence for the Cosgrove and Mitchell sites and moderate repellence at the Forward site. The other sites had very low levels of water repellence. The molarity of ethanol droplet (MED) test was also performed on these samples giving very similar results to the water droplet penetration test. Mitchell nil mouldboard treatment MED was as high as 3.75 moles of ethanol/L indicating very severe water repellence (King 1981).

CONCLUSION

Harvest yield

On average there was a 41 per cent yield response to mouldboard ploughing. The majority of these yield responses were for reasons other than weed density. Weeds were often counted and then sprayed out or were in low density. The Preston site experienced a negative yield response in 2008. This site was sown to canola in 2008. The seeding machinery sank into the mouldboard plots placing the canola seed too deep resulting in very poor crop establishment of mouldboard treatments. The Holmes site was ploughed and sown on 8 June 2008 with Yagan barley. This crop established well but suffered during dry conditions in August and consequently the crop was low yielding and there was no response to ploughing. At all the other sites there were significant yield responses to mouldboard ploughing. We speculate that amelioration of water repellence and simply the effect of cultivation are largely responsible for these spectacular yield responses and further research is required to confirm this.

Weed control

Research into mouldboard ploughing by Dr Sally Peltzer and Alexandra Douglas began in WA to evaluate the use of inversion ploughing for the burial of weed seeds to a depth from which they cannot emerge. All of this research as well as the data presented here shows that in most cases 90 to 95 per cent reduction in weed emergence is achieved after a single soil inversion to a depth of 25 to 30 cm with a mouldboard plough fitted with skimmers (Douglas and Peltzer 2004). This level of seed bank decline typically takes three to five years of 100 per cent weed control (e.g. Chemical fallow) depending on the weed species. There is little doubt that a one-off inversion of sandy soil with a mouldboard plough is going to be a very profitable and effective method of quickly decimating a seed bank of resistant weeds.

Water repellence

The alleviation of water repellence is viewed by growers as possibly the greatest benefit that soil inversion has to offer. Three of the sites studied demonstrate water repellence. Water repellence at the soil surface was completely corrected at two of these sites through soil inversion. The Mitchell site demonstrated some ongoing water repellence after soil inversion. This was the first site that we ploughed in the northern agricultural region and it is possible that the plough was not working at sufficient depth to completely invert the soil. This site also had gravel at depth that caused the plough to jump on several occasions. Further investigation of this site will be undertaken to explain why the soil continues to have water repellence issues after soil inversion. It is interesting to note that the sub-soil at the Cosgrove and the Forward sites was the same texture as the topsoil (i.e. Coarse, gritty sand). So it is merely the absence of wax on the soil that enables this sub-soil to become wettable when it is brought to the surface.

This raises some key research questions. First and foremost is the question ‘what happens to non-wetting soil that is placed at depth’? Previous research by Dr Margret Roper (CSIRO, Perth) has demonstrated that certain soil bacteria have the ability to degrade the wax that causes water repellence provided the soil remains moist for an extended period of time (Roper 2005). In theory, placing the repellent topsoil at depth should result in the soil wetting up due to the surrounding hydraulic pressure, which should in turn allow for the proliferation of the wax-degrading bacteria necessary to degrade the waxy coating. Another key question is ‘how long will it take for the ‘new’ topsoil to become repellent after soil inversion’? This is likely to depend on the amount of clay in the inverted ‘new’ topsoil and the amount and type of organic matter inputs from crop stubbles. With sufficient funding these questions may be addressed with future research.

Sub-surface acidity

The results of lime trials to correct sub-surface acidity have not been reported here. Research is under way at the Preston and Holmes sites to evaluate the effectiveness of burying lime with soil inversion to correct sub-surface acidity. Initial results have clearly demonstrated the ability to raise the sub-surface soil pH by applying lime followed by soil inversion (Newman et al. 2008). As yet there has been no measurable yield response to these treatments. Time will tell if this practice is effective.

Wind erosion

The main drawbacks of soil inversion are the risk of wind erosion and the cost/time constraints. However, we believe that the wind erosion aspect can be managed by cover cropping and the cost/time will be justified by economic yield responses. For effective soil inversion the entire topsoil must be moist to a depth of at least 30 cm. By ploughing in mid-winter (perhaps at the end of seeding) when the soil is wet and immediately (within one day) sowing a cereal cover crop the risk of wind erosion is significantly reduced. For non-wetting soils it can be argued that this leads to a long term reduction in wind erosion risk as improved crop establishment and crop production lead to improved soil cover.

Summary

This area of research is controversial as it goes against the ideals of no-till farming. However, the results of research conducted in recent years are too spectacular to ignore and the acceptance by growers from the NAR has been outstanding. Of the benefits of soil inversion, it is the alleviation of non-wetting soil that is seen as the greatest benefit to growers in the NAR. Growers have been spending up to $700/ha claying non-wetting sands and often getting negative yield responses in following seasons. Other methods of managing water repellence such as use of soil wetters are short-lived and results are variable.

The results obtained to date indicate that a one-off soil inversion using a mouldboard plough in the right situation (particularly deep non-wetting sands) will be very profitable in yield benefits alone and that managing the resistant weeds will be a significant bonus. The mouldboard plough may not be the answer to all of the problems with sandplain farming but it certainly addresses some of the greatest challenges facing this farming system.

KEY WORDS

mouldboard plough, soil inversion, annual ryegrass, wild radish, water repellence, soil acidity

REFERENCES

King PM (1981) Comparison of methods for measuring severity of water repellence of sandy soils and assessment of some factors that affect its measurement. *Australian Journal of Soil Research* **19**, 75–85.

Newman P, Davies S, Peltzer S (2008) Mouldboard ploughing shows promise on sand. Agribusiness Crop Updates, Perth 13–14 February 2008. WA Department of Agriculture and Food. www.agirc.wa.gov.au

Roper M (2005) Managing soils to enhance the potential for bioremediation of water repellency. *Australian Journal of Soil Research* **43**, 803–810.

Douglas A, Peltzer SC (2004) Managing herbicide resistant Annual Ryegrass *(Lolium rigidum* Gaud.*)* in No-Till systems in Western Australia using occasional inversion ploughing. *Proc. 14th Aust. Weed Conf*., Wagga Wagga, 6–19 September 2004.

ACKNOWLEDGMENTS

Many thanks to all of the growers involved in these trials/demonstrations. Sorry to disappoint you Murray but I think it might work! Thank you to Steve Cosh, Larry Prosser, Trevor Bell, and Sam Harburg for their assistance. Many thanks to Dr Sally Peltzer for her insight to get the mouldboard research off the ground. Thank you to GRDC for financial support.

Project No.: DAW0123

Paper reviewed by: Steve Davies

Flaxleaf fleabane—coming to a property near you!

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KEY MESSAGES

- Fleabane seedlings < 5 cm can be controlled with a range of commonly used herbicides.
- Control fleabane seedlings in wheat or barley prior to harvest.
- Large fleabane plants are very hard to kill with a single herbicide application. Use a Group I herbicide followed by Spray.Seed® or paraquat 7 to 10 days later.
- Use robust herbicide rates.

DISCUSSION

Distribution and Spread

Flaxleaf fleabane (*Conyza bonariensis*) is an emerging weed in Western Australia (WA), prevalent along the south coast but spreading to other areas as well. It is an upright, tap-rooted, annual in the daisy family and a weed of both pasture and cropped paddocks but appears to be worse in areas that have recently been cropped. Tall fleabane (*C. sumatrensis*) is also present, possibly more prevalent in the wetter areas. There has been some indication of the two species hybridising in the field although this is as yet unconfirmed.

In Queensland (QLD) and New South Wales (NSW), fleabane is rated as one of the most important weeds of dryland cropping due to its distribution and the difficulty with its control. It was initially a weed of roadsides, particularly where the road shoulders were sprayed with glyphosate (leaving bare soil on which the fleabane could germinate and flourish). It is now widely spread. A recent survey by Western Australian Herbicide Resistance Initiative (WAHRI) in WA found fleabane in mostly roadsides and fence lines with its distribution into cropping paddocks confined predominantly around Esperance. Can we expect fleabane to spread across the WA landscape to become one of our major weeds as well?

Fleabane can spread rapidly due to its abundant seed production and wind dispersal. Mature plants of flaxleaf fleabane produce an average of 110 000 seeds each. Research in the USA has shown that seed of Canadian fleabane (*C. canadensis*) regularly disperses 500 m from source populations, although 99 per cent is found within 100 m. With fleabane's wind-blown seed, it is easy to see how this weed can begin to move into new paddocks and properties.

Emergence and Persistence

Soil types and burial depths have significant effects on seed persistence and emergence. There is an initial rapid germination of seed after rain followed by a slow but steady decline in seedbank numbers over time. Research in southern QLD showed that after three years of burial, there were still viable seeds. In the same study, *C. bonariensis* predominantly emerged from the soil surface with very few seeds emerging from below 1 cm. This emergence from the soil surface suggests that the fleabane problem is a result of weed species shift in the minimum tillage systems which provide moist conditions for better emergence, compared to conventional tillage systems.

Control

In northern NSW and southern QLD, fleabane is a major weed of summer cropping. It germinates either just before or after the crop is sown, competing strongly if left uncontrolled. Because of this, much of the research into the control of fleabane has been on the control of seedlings with knockdowns and post-emergent herbicides. Research highlights include:

- Small weeds were controlled prior to sowing winter crop, using a glyphosate mix, such as glyphosate + 2,4–D.
- The 'double knock' strategy was an effective tool for small fleabane control. It is important that a robust rate of paraquat + diquat (e.g. Spray.Seed®) or paraquat is used to provide control of plants and minimise the likelihood of resistance development of fleabane to glyphosate, paraquat and diquat.

- Glyphosate was relatively ineffective on large plants. Control efficacy was reduced from 88 per cent for weeds 5 cm in diameter to 13 per cent for weeds 10 cm diameter or larger.
- A number of very effective in-crop treatments that achieved 95–100 per cent control were identified, based on use of preplant chlorsulfuron or post-emergent metsulfuron mixes in wheat.

In WA however, fleabane often germinates in spring and early summer prior to harvest. The surface soils in WA are generally wetter for longer in spring compared with northern NSW and QLD. Once the crop is removed, the fleabane has no competition for light or moisture and can grow rapidly, especially with further summer rain. By the time there is a window for control, the fleabane are often large with a large root system, a reduced leaf area and are tolerant to most herbicides. Large infestations of summer weeds have been implicated in reductions in available soil moisture for the following crop resulting in yield losses.

Field trials this year will focus on controlling large fleabane in stubble using a 'double-knock' approach with a range of primary herbicides followed by paraquat 7 to 10 days later. The primary herbicides tested will include Group I herbicides, Group B herbicides and glyphosate among others.

Other control strategies include grazing but it is imperative to let the sheep into the infestations when the plants are young. Also a late spray of 2,4–D after the soft dough or Z87 stage of wheat (see labels) could control the small seedlings in spring avoiding difficult control measures after harvest. This has yet to be registered for fleabane and needs further investigation.

It is unknown whether there are any major agronomic differences between the species that would affect management and control except for flowering times. Flaxleaf fleabane flowers through most of the year, while tall fleabane is thought to flower from December to August in NSW. The biology and phenology of both species will be monitored in WA over the next 2 years. Tall fleabane may be easier to kill with herbicides as it is much less hairy than flaxleaf.

Resistance Status

There is no confirmed resistance of flaxleaf fleabane in Australia. However, one biotype in NSW showed 32 times higher glyphosate tolerance compared to another. Overseas research has documented glyphosate-resistant fleabane as well as resistance to Group B (chlorsulfuron), Group C (atrazine and simazine), and Group L (diquat and paraquat). The WAHRI survey of fleabane found a mixture of both flaxleaf and tall fleabane. Although some of the samples showed natural tolerance to glyphosate, there was no resistance found.

Species Characteristics

Table 1 **Characteristics of the 2 main fleabane species**

	Flaxleaf fleabane	Tall fleabane
Mature plant height (m)	1	2
Stem branching	Branches below each pyramid of inflorescences	Branches only at the inflorescence
Inflorescence shape	Candelabra	Pyramid
Flower colour	White to pink	Greenish-white
Leaf colour	Grey-green	Green

KEY WORDS

flaxleaf fleabane, tall fleabane, herbicides, Conyza

ACKNOWLEDGMENTS

Acknowledgments to Andrew Storrie and Hanwen Wu from DPI NSW and Steve Walker and Michael Widderick from DPI&F Qld for much of the information presented.

Paper reviewed by: John Moore, Andrew Storrie

Trimming weed seed heads and crop-topping reduce seed-bank of wild radish

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KEY MESSAGES

Weed trimming with crop topping with paraquat or Logran® dramatically reduced seed set of wild radish.

Weed trimming alone removed 62% of the wild radish pod at the time of trimming but with late rain the final pod number was not reduced.

AIMS

1. To examine if weed seed heads could be mechanically removed before weed seeds mature using a swather or header.
2. To assess the effect of crop topping after mechanical weed seed removal on the reduction of weed seed set.

METHOD

The experiment was established at the Merredin Research Station paddock 8DE which has a wild radish seedbank. No pre-emergent chemicals were used apart from a knockdown. The experiment was a randomised block with 4 replications.

Experiment details

Sown:	14 May 2008 at 33 cm row spacing using press wheels and 180 mm outside diameter ring harrows sown with a 13 row combine.
Seed:	Mandelup lupins at 91 kg/ha with Rovral seed treatment.
Fertiliser:	79 kg/ha double super (17.7% P, 16.2% Ca, 3.6% S, 0.08% Zn, 0.08% Cu) banded 2 cm below the seed.
Sprays:	24 April 2 L/ha Roundup® PowerMax + 0.025 L/ha Hammer. 14 May 2 L/ha Spray.Seed® 250. 6 and 10 October 0.1 L/ha Dimethoate®. 20 October 0.035g/ha Logran® on selected treatments. 20 October 0.8 L/ha Reglone® on selected treatments. 20 October 1.0 L/ha Roundup® CT on selected treatments. 23 October 0.2 L/ha Fastac Duo®.
1st trimming:	7 October with Case 2366 header with 36' front modified for swathing and using pink extension fingers on every 2nd knife guard and 2 ply 6 mm insertion rubber sweeps on the reel (Figures 1 and 2).
2nd trimming:	20 October.
Harvest:	2 December (plots were harvested in the direction of sowing to reduce header bounce).

Treatments

1. Untreated control.
2. Weed seed head removal at maximum flowering stage of the weeds.
3. Weed seed head removal at late flowering stage.
4. Weed seed head removal at maximum flowering stage and again at late flowering stage.
5. Weed seed head removal at maximum flowering stage followed by crop topping with glyphosate 1 L/ha on new growth.
6. Weed seed head removal at maximum flowering stage followed by crop topping with paraquat 800 mL/ha.
7. Weed seed head removal at maximum flowering stage followed by crop topping with Logran®.
8. Crop topping with paraquat 800 mL/ha.

Figure 1 Weed trimming at Merredin on 7 October 2008.

Figure 2 Primary Sales Adapter-Gap pink extension fingers and rubber sweeps on reel.

RESULTS

The average lupin plant density was 28/m^2, which is low and may have been due to the dry start to the season (total May-June rainfall was 40.4 mm vs long term average of 95 mm).

The lupin yield showed no differences between treatments (Table 1), which is a good result as there was some reduction in yield from trimming too close to the top of the crop canopy at Merredin in 2005.

The wild radish seed number in the harvested lupin seed showed that early trimming plus paraquat or Logran® reduced the wild radish seed number dramatically (Table 1). Some of this reduction may be due to pods shed before harvest. However, the Log (x +1) transformation of pod number in the harvested seed was significantly different which suggests the trimming plus paraquat was more effective than just paraquat, assuming the same amount of pod shedding.

Table 1 **Machine harvested grain yield of lupin and wild radish seed number in the harvested lupin seed sample (taken on reps 1–3 as rep 4 was too variable)**

Treatment	Lupin yield (t/ha)	Wild radish in lupin seed (seeds/m^2)	Log (x +1) transformed wild radish (seed/m^2)
1. Untreated	0.597	38	1.307
2. Trim early	0.586	79	1.779
3. Trim late	0.710	39	1.468
4. Trim early and late	0.564	79	1.813
5. Trim early + glyphosate	0.701	30	1.327
6. Trim early + paraquat	0.754	5	0.592
7. Trim early + Logran®	0.855	7	0.666
8. Paraquat	0.575	14	1.012
P value	0.208	0.014	< 0.001
l.s.d.	not significant	45	0.305
CV%	24.5	70.8	13.9

Before trimming some selected wild radish plants with no wild radish plants within close proximity were tagged and the pods counted, including ones fallen on the ground. The average reduction in pod number when trimmed was 62% but with an extra 61 mm of late rainfall (September-November received 120 mm vs long term average of 59 mm) stimulating regrowth, the final pod number, just before harvest, tended to increase (Table 2). However, the early trim with later paraquat or Logran® again showed a marked reduction in final pod number on 25 November, similar to that found in the harvested seed. It was unfortunate that the paraquat alone treatment was not sampled as this would have given a clearer indication of the effectiveness of trimming + paraquat over just paraquat.

Table 2 **Average wild radish pod number on individual plants, before and after trimming (on 7 and 20 October 2008) and following additional 61 mm of rainfall (11 and 25 November 2008)**

Treatment	7 October 2008		20 October 2008		11 November 2008	25 November 2008
	Before	After	Before	After		
1. Untreated	280	280	ns	ns	525	635
2. Trim early	47	24	ns	ns	94	184
3. Trim late	ns	ns	145	70	70	213
4. Trim early and late	281	0	44	35	134	327
5. Trim early + glyphosate	255	160	ns	ns	ns	ns
6. Trim early + paraquat	350	73	ns	ns	24	67
7. Trim early + Logran®	52	2	ns	ns	19	41
8. Paraquat	ns*	ns	ns	ns	ns	ns

*ns = not sampled.

CONCLUSION

Weed seed trimming alone was not effective in reducing wild radish seed production in this season with an un usually wet spring (September-November received 120 mm vs long term average of 59 mm), but with added paraquat or Logran®, the wild radish seed number was reduced markedly. Further, crop yield was not affected.

KEY WORDS

weed trimming, wild radish, lupin yield, seed set

ACKNOWLEDGMENTS

The authors would like to thank Al Harrod, Manager of the Merredin Research Station, Aaron Middleton for seeding, Leanne Young for spray treatments and harvesting and Elmer Kidson for the weed trimming.

Project No.: DAW00158

Paper reviewed by: Catherine Borger