Controlling patches of glyphosate-resistant weeds: is victory possible?

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Summary Management of weeds is frequently undertaken on a whole of paddock perspective. This is more often a result of weeds occupying a large proportion of the paddock. However, earlier intervention could prevent this from happening.

Four case studies investigating four different weed species has demonstrated a variety of ways farmers have managed patchy glyphosate resistant weeds. A common link between all case studies is the well apportioned use of chemical and non-chemical tactics. In addition, a common theme is the use of patch specific treatments superimposed by whole of paddock treatments and an understanding that weed seed production / prevention contributes to population development / decline.

Gauging the level of success for these case studies is a subjective measurement. The opinion of effective control can be highly variable; as some farmers consider total eradication the end point whereas others may consider maintaining or gradually reducing patch size a form of success.

These case studies have shown that management of patchy glyphosate-resistant (GR) weeds can result in positive outcomes. Some improvements have been identified to further reduce weed patchiness, namely fence line weed control. Despite this, an overriding feature of these case studies is the early action taken and the persistent objective of farmers to push for victory in the battle against patchy weeds.

Keywords Glyphosate resistance, patch management, eradication, integrated weed management, annual ryegrass, *Lolium rigidum,* awnless barnyard grass, *Echinochloa colona,* feather-top Rhodes grass, *Chloris virgata,* liverseed grass, *Urochloa panicoides*.

INTRODUCTION

Literature reporting broad-acre glyphosate-resistant weed control occasionally provides research or advice on the management of small patches. Good examples of such research have either used computer modelling (Thornby *et al.* 2014) or interim field results that required more time to validate success (Werth *et al.* 2014). Despite the lack of field based evidence, there are many farmers trying to manage these patchy situations. Therefore, it would be more prudent to have information that could prevent new glyphosate-resistant weed patches spreading beyond the early phases of establishment, using examples from case studies.

Most of the emerging glyphosate-resistant issues are emerging from the northern grains region of New South Wales and Queensland. This is predominantly due to the overuse of glyphosate in the fallow period and the diversity of weed species in this region. It is therefore common to find examples where glyphosate-resistant weeds are affecting a small proportion of a paddock. In some cases, if little or no intervention is practiced, the problem will spread beyond the patch stage. Developing patch management advice to growers in the north is therefore a high priority.

There is a good variety of weed management tactics that can be used for patch management (McGillon and Storrie 2006). Combinations of chemical and non-chemical methods are being used by grain growers with varying degrees of success. Although there are few examples of eradication, success can also be seen as containing or reducing the size of patches, preventing them from affecting large proportions of the farm.

In this paper, a total of four case studies will be examined. All of these are based within the northern grains region. Each will focus on a different glyphosate-resistant weed. The species investigated are annual ryegrass (*Lolium rigidum* Gaudin), awnless barnyard grass (*Echinochloa colona* (L.) Link), feather-top Rhodes grass (*Chloris virgata* Sw.), and liverseed grass (*Urochloa panicoides* P.Beauv.).

MATERIALS AND METHODS

All case studies were completed as face to face interviews of farm managers in spring and summer of 2015/16. A set list of questions were asked and explanation of some responses were required if the interviewer deemed it was required, particularly if the response was not specific enough.

The structure of the questionnaire and the some of the questions about critical aspects of management are listed in Table 1. Background information of the property was first investigated; giving a snap-shot of the property operations at the time of interview. The next

section is characterized by questions that investigated what happened prior to the confirmation of resistance. Accordingly the next group of questions dealt with the management decisions and tactics required to deal with the patchy weeds. Finally the last section of responses was directed at evaluating the result of their changed management tactics.

Case study 1 investigated GR annual ryegrass within Central West slopes of NSW, near the town of Coolah. The second case study, at Pallamallawa within North West plains of NSW focused on GR liverseed grass. Case studies 3 (GR awnless barnyard grass) and 4 (feather-top Rhodes grass) were located in the western (Tara) and eastern (Dalby) Darling Downs region of southern Queensland, respectively.

RESULTS

Case study 1 (annual ryegrass) This case study highlights the attempts to manage GR annual ryegrass in a mixed farming system. The 18000 hectare property, located near Coolah, has 5000 ha devoted to cropping and 3000 ha for dual purpose cropping and pastures. There is opportunity to rotate from winter to summer crops (sorghum) for management flexibility and herbicide choice.

Glyphosate resistance was suspected in 2009 and tested soon afterwards. It was thought to have originated on the property due to over reliance on glyphosate based products. The rotation in the past had three seasons of sorghum followed by wheat then canola. Patches can be seen in the middle of paddocks and along fence lines, a consequence of glyphosate resistance. Approximately 30 to 40% of cropping paddocks are affected by GR annual ryegrass with 10% being termed 'a real problem'. Some of the annual ryegrass (ARG) movement can be attributed to movement down a slope following heavy rainfall. Sheep and the occasional cultivation have been used as non-chemical methods for control, although the manager admits the cultivation was used mainly for other purposes.

What is the approach to manage the GR ARG? The cropping rotation has changed to a canola/sorghum/chickpeas/barley and dual purpose wheat cycle. This allows annual ryegrass control with a robust range of modes-of-action chemistry. The ARG populations on this property were still susceptible to Group A herbicides and most pre-emergence options. Paddocks that are not infested by GR ARG, are treated as though they have GR ARG, with similar cropping system changes to ensure herbicide choice flexibility. The farm manager has also considered dryland cotton to add more summer options.

Table 1. Structure of the questionnaire and type of information sought.

BACKGROUND INFORMATION
Farm location (town, region and state), size of property (area devoted to cropping and grazing), types of enterprises (specific crops grown, stock type), a description of the climate (annual rainfall and whether it is summer or winter dominant), use of any conservation farming techniques – if yes what types are used and the reason for implementing them, number of years the owner has managed the property, information about current resistance issues, resistance patch sizes and where on paddocks are they located – this can be supported by photographic evidence of some resistance patches
HISTORY
What year was glyphosate first suspected of losing efficacy, what year was glyphosate resistance confirmed, likely cause of resistance, any other weed species of concern (what modes of action are they resistant to), cropping rotation and details about the integrated weed management used over that cropping cycle
DEALING WITH THE PROBLEM
Who is involved in developing the weed management plan and how are they involved, where is weed management information sourced from (e.g. agronomist/government advisor/other framers/grower advisory days/written material etc.), describe the changes in crop rotations, describe changes to whole of paddock treatments, describe any specific patch management treatments, are any of the stages of the weeds' life cycle targeted (e.g. actions taken to stop weed seed set), what measures are taken to prevent weed movement (e.g. weed control in non-crop areas, wash down vehicles after travelling through weed patches etc.), monitoring (e.g. frequency of inspections and areas on property more frequently inspected than others) ,duration of patch management activities/plan or is the management of patches more reactive
RESULTS AND REFLECTIONS
Describe how the patch size has changed over time, are outlier patches detected, what are barriers to adopting other techniques, anything challenging with new strategies and how were they overcome, comment on any failures with some treatments, recommendations to other farmers, profitability of changed weed management – have benefits been seen in other farm enterprises, how many years will it take to get problem under control, improvements – could things have been managed better?

Some difficulties encountered were the availability and timeliness for spraying operations. Machinery is a limiting resource and the advent of double knocking has restricted the availability of spray rigs.

Fence line weed management was a reasonable concern. The manager did not know of alternative options for this situation. However, whilst the case study interview was being conducted, NSW Department of Primary Industries advised him of alternative options. Furthermore, there were some fallow pre-emergence options that were discussed that would find a good fit into the cropping rotation.

A positive aspect of this case study was the understanding that the manager knew that stopping weed seed set was the key to success. In summary, the manager has minimised the spread of this weed but wants to take it one step further and reduce weed seed banks significantly.

Case study 2 (liverseed grass) A 600 ha farm, located at Pallamallawa was acquired by the current owner in 1998.

Approximately 10 paddocks are used in a barley/chickpea/wheat/long fallow and summer crop rotation. Resistance was suspected and tested in the summer of 2007/08 and confirmed glyphosate resistant. The resistance is believed to have been the consequence of many years of consecutive applications of glyphosate with poor cultivation thereafter (not full disturbance).

The patch of liverseed grass is relatively small, about one hectare. The farmer now has managed the property for 18 years and has recently said in the case study interview, "I'm sure I have won this battle."

What is the approach to manage the GR liverseed grass? For this case, the patch was contained and very small, thus would allow the farmer to "throw the kitchen sink at it". The objective of the farmer was to eradicate the patch; most of the tactics mentioned further on were specifically directed at the patch. Thereafter, in 2009 the patch was treated with herbicides using alternatives modes-of-action to glyphosate. Cultivation was used frequently and changed to full disturbance (wide sweeps) so that nothing could survive. Very importantly the patch was monitored closely to check that the job resulted in 100% control. Double knocking was used to good effect along with pre-emergence herbicides.

One year in the rotation a winter cereal was brown manured and the biomass was used as mulch in the period that liverseed grass would normally emerge.

The farmer stated one noteworthy comment in relation to managing his resistance, "Get onto it", confirming his intention to avoid procrastination and to take control. The result of this case study is what could be seen as eradication. However, since being affected by resistance this farmer is always on the lookout for other potential small patches of resistance or hard to control tolerant weeds.

Case study 3 (awnless barnyard grass) A mixed farming property located near Tara, Queensland, consisting of 1750 ha cultivation/farming paddocks and 500 ha pasture has infestations of GR awnless barnyard grass and feather-top Rhodes grass (FTR). The glyphosate resistance status of the FTR was unknown. Glyphosate resistance in awnless barnyard grass was confirmed in 2012 and again in 2015, reportedly surviving glyphosate (450 g a.i L^{-1}) at 4.5 L ha^{-1}. FTR was first seen in 2012 and has progressively got worse. Glyphosate was the only herbicide used and often it may be applied 3 to 4 times per fallow. The owner and agronomist blame the lack of chemical group rotation for their problems.

The cropping rotation is wheat/wheat/wheat/long fallow/sorghum/sorghum and long fallow (duration of long fallow approximately 16 months).

What is the approach to manage the GR awnless barnyard grass? Having major changes to chemical and non-chemical options has led to improved results. By having an occasional long fallow it has allowed the option to use cultivation if weed 'blow-outs' occur. However, pre-emergence herbicides are now frequently used, namely imazapic (prior to wheat) and metolachlor (in preparation for sorghum). WeedSeeker® technology (Brownhill 2006) is used for isolated patches but requires high rates of glyphosate to manage the problem.

The results are mixed. It appears the FTR can be managed due to residual herbicides, cultivation and WeedSeeker®. The awnless barnyard grass still remains the issue. The owners treat the affected paddocks differently to the rest of the farm. Currently the practice of extremely high rates of glyphosate via a WeedSeeker® are working well but they struggle to justify the cost of the more expensive Group A options and understand most of them are not registered for use. Adjustments to some activities have been implemented since resistance. Now sheep are used as a second knock after the initial spray whereas previously they were used as the first knock, making plants less susceptible to herbicides when used as the second knock.

Attempting to patch spray many isolated patches on a large property was a difficult task and many outlier plants were missed and allowed to set seed. Therefore over time some patches have slowly expanded. The management rule applied within this property is to

make overall changes to paddock-wide treatments so that the time consuming effort of spot treating can be avoided. Fence line weed management is very active on this farm, the choice is to either allow native grasses to colonise these areas to provide some competition to the weedy grasses or they use an array of herbicides with no consistent pattern around the farm.

In summary, the owners of this property are still reasonably happy with their outcome as they know that if they continue with the glyphosate based fallow strategy, the property would be fully infested with awnless barnyard grass and FTR. They surmised the main treatment for control in this situation would be to resort to cultivation in every paddock several times per year.

Case study 4 (feather-top Rhodes grass – FTR) A 1350 ha farmer-owned property near Dalby was used for this report. The split between winter and summer cropping is about 75:25. Prior to the discovery of FTR the cropping rotation was sorghum/sorghum/sorghum/chickpea and long fallow. The first sighting of the weed commenced soon after the floods of 2011. Rapid change was made in response to this new weed incursion as FTR was widely known as a troublesome weed around the Darling Downs. The largest patch on the property was 5 ha.

What is the approach to manage the GR FTR? A change in cropping rotation was the first action. One sorghum crop was substituted for wheat and additional barley followed, then mungbeans. As such the new rotation is now sorghum/sorghum/chickpeas/wheat/barley and mungbeans. By incorporating additional winter crops, more summer fallows can allow better surveillance of the summer growing weed and permit the use of some pre-emergence herbicides. Some paddock-wide treatments are employed in the summer fallow to gain control. The pre-emergence herbicide imazapic is sometimes used depending on plant-back restrictions (ideal prior to winter cereals). Thicker patches are also treated with haloxyfop followed by paraquat as a double knock. However, some of the critical management tactics used are hand chipping the occasional isolated plant or using fire to burn isolated mature plants that have a good seed load. If patch size warrants the need, the farmer patch cultivates.

Delayed sowing of summer crops is a tactic this farmer uses so that cultivation can be used to control early season emergence of weeds. Other summer crop options are the use of pendimethalin and imazethapyr in mungbeans and metolachlor and atrazine in the sorghum phase.

Fence line management is either the use of haloxyfop tank mixed with glyphosate or promoting non-weedy grasses as a form of competition against FTR. The property seemed nearly 100% clean of FTR along the fence lines so internal farm hygiene must be a high priority.

The five hectare infestation that was the largest is now isolated plants due to sacrificing part of a chickpea crop by using glyphosate then burning the dry remains.

In conclusion, this farmer is very strict about his FTR patch management. He used combinations of non-chemical and chemical tactics and sets rules for various scenarios. For example, if the FTR is between 5 and 15% of the paddock he would use blanket treatments, if between 1 and 5% the WeedSeeker® would be used and infestations less than 1% he would consider hand removal.

This farmer had shown that monitoring, determination and setting plans are crucial factors to success.

DISCUSSION

There is no set recipe for successful patch management of glyphosate resistant weeds. However common themes appear within many of these case studies.

It appears some keys to winning the battle include:

- Maintain the pressure on the weeds by using effective treatments regularly.
- Always undertake chemical and non-chemical options.
- Get the weed patches early, if possible.
- Consider using pre-emergence herbicides and cultivation in fallows.
- Optical Spot Spray technology is useful.
- Fence line management is critical.
- Consider the battle may go on for at least 5 to 10 years.
- Farm hygiene practices must be used.
- Monitor every paddock after every treatment.
- Patch treatments are complementary to paddock-wide treatments.
- Stop weed seed set.

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REFERENCES

Brownhill, D. (2006). Using 'Weedseeker'spot spraying technology in cropping systems. Proceedings of the10th Annual Symposium on Precision Agriculture in Australasia.

McGillion, T. and Storrie, A. (2006). Integrated weed management in Australian cropping systems – a

training manual for advisors. CRC for Australian Weed Management, Adelaide, Australia.

Thornby, D., Werth , J. and Walker, S. (2014). Patch management solves early infestations of glyphosate resistant awnless barnyard grass. Proceedings of the 19th Australasian Weeds Conference, Hobart, ed. M. Baker, pp. 214-7. (Tasmanian Weed Society, Hobart).

Werth, J., Thornby, D., Keenan, M. and Walker, S. (2014). Managing patches of glyphosate resistant *Echinochloa colona*: can they be eradicated? Proceedings of the 19th Australasian Weeds Conference, Hobart, ed. M. Baker, pp. 3-6. (Tasmanian Weed Society, Hobart).