Winter 2015

GRDC
Grains Research & Development Corporation

giving a RATS

INTRODUCTION

Newsletter of :
"GRDC Project UA00124 – Understanding and management of resistance to Group M, Group L and Group I herbicides"

This is the final "Giving a RATS" newletter, as we know it. (Editor wipes a tear from his eye). The GRDC Project UA00124 – "Understanding and Management of resistance to Group M, L & I herbicides" comes to an end as of June 30, 2015.

The first edition of "Giving a RATS" was published in Autumn 2012. People who haven't see the first issue probably wondered about the name.

- **R**esistance – looking at the latest research and extension on resistance to Groups M, L and I
- **A**pplication – If you don't get the herbicide application right you are effectively under-dosing the weeds
- **T**actics – We know we can't rely solely on herbicides so what non chemical tactics must we employ?
- **S**ystems – Because every individual farmer and their farm are different advice cannot be proscriptive and must be adapted for each situation.

The project had the following lofty goals, and hopefully the team came at least part way to fulfilling these:

- Improve the knowledge of glyphosate, paraquat and 2,4-D resistance by:
- Improve skills to build confidence in the adoption of integrated weed management by:
- Build the motivation and aspiration for grain growers to adopt improved integrated weed management for Group M, L and I resistance.

In this final edition Project Leader Chris Preston highlights the achievements of the project. It is time to consider testing for herbicide susceptibility using the Quicktest, Tony Cook philosophises on spray versus cultivation for BIG fallow weeds, and Abul Hashem reminds us that fixing soil problems also helps weed management. Tony Cook comes back again with some project research on alternatives for controlling resistant wild radish, while Andrew Storrie reminds us that better spray application leads to better control. And a final note from our North American cousins – they have agreed on a definition for "Superweeds". I can now sleep peacefully.

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"And a big thank you to the GRDC for funding this project and newsletter."

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> *"The good thing about science is that it's true whether or not you believe in it."*
>
> *Neil de Grasse Tyson 1958-*

WHAT HAVE WE LEARNED ABOUT RESISTANCE TO GLYPHOSATE, PARAQUAT AND THE PHENOXY HERBICIDES OVER THE PAST 4 YEARS?

Each of these herbicides plays important roles in the Australian agricultural system, roles that are hard to replace with other herbicides. Therefore, there is a need to protect these modes of action from the development of resistant populations of weeds. The amount of resistance we are finding in Australia to each of these modes of action is increasing, making the need for action more urgent.

GROUP I

Group I herbicide resistance in sowthistle (*Sonchus oleraceus* - AKA milk thistle / sowthistle) from South Australia has recently been reported. This population has resistance to 2,4-D, dicamba and clopyralid, suggesting none of the Group I herbicides will be effective. 2,4-D resistance in wild radish (*R. raphanistrum*) is common in Western Australia and a growing problem in the eastern States. The first cases of 2,4-D resistance in wild radish from Victoria and South Australia have been reported in the past 4 years.

2,4-D resistance in Indian hedge mustard (*S. orientale*) was reported in South Australia a few years ago. This population was also resistant to the Group B herbicides. It had a target site mutation giving resistance to Group B herbicides, but as yet the mechanism of resistance to 2,4-D is unknown. Inheritance of 2,4-D resistance is due to a single major gene, which illustrates that it may be easier to select for resistance to the Group I herbicides than was previously thought.

Paraquat

Paraquat resistance was identified in Australia in annual ryegrass for the first time, firstly in irrigated pasture seed production fields and then in vineyards. This is an extremely worrying development as paraquat is an important alternative to glyphosate in many circumstances. It illustrates the problems with relying solely on paraquat to control weeds. More recently, paraquat resistance has been identified in crowsfoot grass and cudweed from sugar cane fields and plantations in Queensland.

Paraquat resistance in annual ryegrass is due to reduced translocation of paraquat. This mechanism is similar to one of the mechanisms for glyphosate resistance, but is a due to a different gene. The inheritance is as a single, partially dominant allele.

Glyphosate

During the past 4 years there has been an increase in the number of weed species identified in Australia with glyphosate resistant populations. These include great brome in SA and Victoria, sweet summer grass in Queensland, windmill grass in NSW and Victoria, and sowthistle in NSW. In addition, there have been large increases in reports of glyphosate resistance in annual ryegrass, barnyard grass and fleabane.

Mechanisms

It is becoming increasingly obvious that there are numerous mechanisms of glyphosate resistance available to plants. Annual ryegrass tends to have reduced glyphosate translocation or target site mutations. Brome grass is the first weed discovered in Australia where resistance is due to massive gene amplification. Some barnyard grass populations contain target site mutations, but others do not indicating multiple mechanisms of resistance are present in this species. One feature of glyphosate resistance in barnyard grass is that many populations become more resistant to glyphosate as temperature increases. This is in part due to lower uptake of glyphosate. This makes management of glyphosate resistant barnyard grass populations more challenging.

Fencelines

Glyphosate resistance on crop margins and fence lines was identified as a particular problem by the project. Considerable work to raise the profile of this issue has been conducted across the country, highlighting the need to successfully manage weeds in this area. Trials conducted during the project identified bromacil as a useful herbicide to have in a mix along certain fence lines to control glyphosate-resistant and other weeds. The registration of Uragan® by Adama for fence-line use has increased the options available to farmers.

Figure 1. Extending the 'clean fenceline' message at Wagin, WA. Image: AGRONOMO

Considerable work has been done in the project to refine double knock strategies for glyphosate-resistant barnyardgrass and to identify strategies that may work with glyphosate-resistant sowthistle; however, control of glyphosate-resistant weeds in fallows remains a significant challenge.

A number of resources have been created to help agronomists and farmers to make better decisions in managing resistance to these herbicides. An updated version of RIM for ryegrass management was developed and is available from the AHRI website. RIM is particularly useful for looking at the possible financial and ryegrass population outcomes of taking one management strategy compared to another.

The project has produced a series of fact sheets and case studies that look at specific management issues are available from the AGSWG website and the WeedSmart website. More of these will come in the next few months. These are a valuable resource in showing how growers have managed these issues. The key elements that come out time and again are a willingness to adopt new strategies and a take no prisoners approach to managing problem weeds. The Giving A Rats newsletter, of which this will be the final issue, has also provided information and tips for managing M, L and I resistant weeds and better spray management. The Glyphosate Resistance Register is also available from the AGSWG website.

This project has contributed greatly to better understanding of glyphosate resistance and to the tools for better management of glyphosate resistance in annual ryegrass. It has also highlighted that there are considerable challenges to managing resistance to the Group I herbicides and glyphosate-resistant weeds in fallows. It has been an interesting 4 years and I would like to thank the researchers in the team for their work and GRDC for funding the project. Most of all, I would like to thank the many agronomists and growers who contributed ideas, needs and trial sites to the project.

Chris Preston

Project Leader

University of Adelaide

Figure 2. Brome grass Image: AGRONOMO

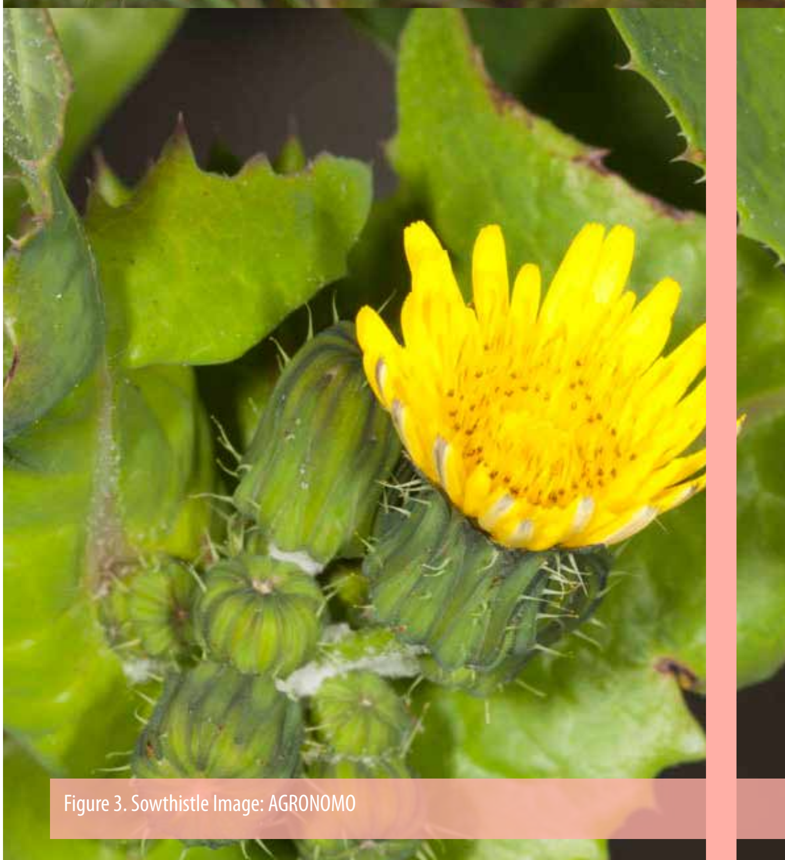

Figure 3. Sowthistle Image: AGRONOMO

Herbicide resistance weeds are now starting to drive the farming system in many areas limiting enterprise options for growers and reducing crop yields. A 2013 survey in Western Australia showed that over 40 per cent of annual ryegrass plants submitted had some level of glyphosate resistance (Giving a RATS Newsletter Edition 8 Autumn 2014 p 4).

There is still an opportunity this season to determine what is happening in your paddock that will let you make weed management decisions before harvest. This is the Quicktest.

Unfortunately only a small percentage of growers test for herbicide resistance, usually as a reaction to a herbicide failure, and an even smaller percentage use resistance testing as a part of their overall weed management program.

Part of the problem is that many growers are unknowingly spending thousands of dollars on herbicides that are giving poor levels of control while others are using expensive herbicides to tackle resistance when older and cheaper herbicides are still be working.

Also many growers are now experiencing reduced levels of ryegrass control from clethodim (e.g. Select®) due to resistance. Will butroxydim (Factor®) give better control of these problem grasses? No-one knows because there is already cross resistance to butroxydim in some ryegrass populations. The only way to be sure is to either spray the paddock with butroxydim and wait, or do a susceptibility test.

Are their survivors of your pre-sowing knockdown or an early post emergent herbicide? Why did these plants survive? Application error, stress or resistance?

What we need to do is turn resistance testing on its head and test for what still works!

What is the Quicktest?

Most farmers know about collecting seed at the end of the season to send for testing with results usually coming back in March.

The Quicktest on the other hand is the collection of live plants which are 'expressed posted' to the laboratory, trimmed, re-potted then sprayed with the herbicides of your choice following discussion of the relevant options. Results are available in 3 to 4 weeks enabling effective management decisions to be made this season to prevent viable seed being produced by these resistant weeds.

Stopping seed set is the ONLY way to manage herbicide resistance.

Quicktest is ideal for pre-seeding or early post emergent herbicide survivors. Why didn't those weeds die? What will you do about it?

NOTE: Quicktest is only suitable for post emergent herbicides such as glyphosate and paraquat or in-crop selective herbicides. To test for pre-emergent herbicide resistance, particularly trifluralin, you must use the seed test.

For more information on Herbicide Susceptibility Testing and the Quicktest go to http://www.agronomo.com.au/herbicide-suscept-testing/

Figure 4. Crop of faba beans with a huge ryegrass infestation which has already been treated with a pre-emergent herbicide then clethodim. What would you do next? Image: AGRONOMO

Figure 5. What to do when the weeds get to this size? Image: T. Cook

Figure 6. Cultivation works well under the correct conditions. Image: T. Cook.

Despite the best of intentions, getting the ideal timing for herbicide applications sometimes falls well short of text book perfect weed control. Occasionally a string of unfavorable events, such a prolonged dry conditions followed by floods, can allow fallow weeds to obtain phenomenal sizes.

With this in mind we were 'fortunate enough' to find a fallow site near Moree, NSW, infested with enormous awnless barnyard grass plants with some having over 500 tillers. How can these large plants be killed? Are there any herbicides that could be an alternative to cultivation? Current thinking is that once awnless barnyard grass is bigger than 15 to 20 tillers herbicide control is virtually impossible.

The co-operating farmer resorted to blade plough these large plants with moderate success. However, the plough could not cut through thicker infestations and was forced to the surface. Using an off-set disc would seem like 'the devil's work' to many however sometimes we get to the point of "whatever it takes".

It was also a good opportunity to test two of the latest Nufarm® Optical Spot Spray Technology label treatments - paraquat (250 g/L) at 3 to 9 L/ha and glyphosate (470 g/L) at 3.5 to 7 L/ha.

The farmer suspected glyphosate resistance so demonstration plots were sprayed with glyphosate (450 g/L) at 2, 4, 6, 8 and 10 L/ha to determine if there was glyphosate resistance and if so the level.

An assessment made three weeks after application showed the rate response was sluggish with the top rate of 10 L/ha giving only a moderate brownout of foliage. This population of awnless barnyard grass demonstrated higher levels of glyphosate resistance than most of samples sent in for testing over the past 5 years for the northern grain region.

High rates of paraquat

In mid-March 2015 we also investigated the effect of rate and diurnal timing of paraquat. The treatments were applied under daylight and darkness (sunset). Previous research has shown some benefit of applying paraquat in the evening compared to standard daylight applications. What occurs is that paraquat has more time to translocate through the plant before the sunlight activates the herbicide.

Table 1: Effect of a single application of paraquat on large awnless barnyard grass plants (24 days after treatment)

Treatment	BYG alive per plot (2 m x 10 m)	
	Day	Night
untreated	210	
paraquat 2 L/ha	46	19
paraquat 3 L/ha	59	14
paraquat 6 L/ha	12	0
paraquat 9 L/ha	3	19

Again it was shown that evening applications of paraquat were more effective than those applied in direct sunlight with 3 L/ha in the evening was equivalent to 6 L/ha applied under sunlight.

Control with paraquat showed a substantial jump in control between the 3 and 6 L/ha rates in daylight. Field experience would suggest two consecutive applications of paraquat at the lower rates would have achieved a high level of control.

Another experiment at the same site compared haloxyfop (Verdict®) in combination with paraquat (2 L/ha) either as a double knock, or applied alone. The results reiterated that haloxyfop, regardless of rate used, is ineffective at controlling tillered and flowering barnyard grass.

These findings suggest that if growers have to control large awnless barnyard grass escapes it is possible at a price, although large quantities of seed have been produced and soil water used. There is no substitute for early control by using pre-emergence herbicides and/or early post-emergence knockdown options.

Figure 7. Unsprayed barnyard grass. Image: T. Cook.

Figure 8. At 10 L/ha glyphosate (450 g/L), it looks like a bad case of glyphosate resistance. Image: T. Cook

Figure 9. A slight increase in efficacy with applying paraquat just before dark. Image: T. Cook

Choosing either chemical or cultivation to control large weeds should be discussed with your adviser. Cultivation can bury seeds deeply and extend the life of the seedbank. Furthermore, damage to soil structure may occur if done when too wet or too dry.

The farmer is now using paraquat to successfully manage barnyard grass.

Tony Cook

NSW DPI Tamworth

Figure 10. "Has the horse bolted?" Large plants using moisture and dropping thousands of seeds. Image: T Cook

DON'T JUST LOOK AT HERBICIDES, USE LIME ON ACIDIC SOILS FOR WEED SUPPRESSION

Figure 11. The effect of 5 t/ha lime in 1991 on the competitive ability of barley with annual ryegrass in 2010. Image: C. Gazey.

DAFWA field research investigating the impact of lime and herbicides on annual ryegrass and wild radish numbers in low pH soils has found that applying at least at 2.5 t/ha of lime is a valuable tool to reduce impact of wild radish and annual ryegrass in addition to other benefits from lime. The research was conducted at four locations in Western Australia from 2010 to 2014.

The effect of lime on wild radish density at Eradu

There was no effect of lime on wild radish density in the first two seasons following application due to the use of lime sand as opposed to a more available form of lime.

However in 2013, the density of wild radish decreased by up to 48 per cent with 2.5 t/ha and 5 t/ha of lime.

For more information go to https://www.agric.wa.gov.au/soil-acidity/benefits-maintaining-appropriate-ph-profile

Abul Hashem
Department of Agriculture and Food WA,
Northam

Table 2. Effect of lime on the density of wild radish per square m measured three weeks after crop emergence but before application of post-emergent herbicides at Eradu in 2013. Note this was three years after the initial lime application

Lime Application (t/ha)	Wild Radish (plants per sq. m)
0	120
1.25	105
2.5	63
5.0	66

At all sites, the pH in the sub-surface layers (20 cm or deeper) with or without lime remained below what is recommended for optimal root growth suggesting that soil acidity at depth was still restricting barley crop root growth in the 4th year.

The results reinforce the fact that lime takes a long time to move down the soil profile to alleviate the soil acidity problem but lime application can lead to reduction in weed burden after a few years.

Within twelve months of announcing the first Group I resistant wild radish infestation in NSW, our keen research team has completed a wild radish control experiment at Nyngan testing many herbicides with different modes-of-action. A primary aim was to show growers that there is more to wild radish than relying on 2,4-D. Treatments contained groups B, C, F, G, H, I and M. Although the trial was in a wheat crop, the trial included some wheat damaging herbicides such as glyphosate, atrazine, imazethapyr and isoxaflutole. These herbicides were used to show growers that other modes-of-action are effective in broadleaf crops.

This trial site did not have much Group I resistant wild radish because the early application of 2,4-D achieved excellent control, however delaying the application to flowering reduced radish control by 20 per cent. Pyrasulfotole + bromoxynil (Velocity®) is currently giving excellent control of Group I resistant wild radish in Western Australia although over-reliance is likely to lead to pyrasulfotole resistance. Pyrasulfotole + bromoxynil was also highly effective in this trial along with MCPA + bromoxynil + diflufenican (Triathalon®), pyrasulfotole + MCPA (Precept®), diflufenican and early MCPA with or without either diuron.

Results (Table3) show that the glyphosate treatments gave poor control of radish. The data indicate that seedlings that emerged soon after treatment and were not controlled while the emerged plants were controlled.

Some herbicides such as bromoxynil were applied outside the optimum application timing and too low a rate for adequate control. Herbicides such as atrazine and isoxaflutole are best applied pre-emergent however 80 per cent control of 4 to 8 leaf radish indicates these herbicides have some post emergent activity.

Tony Cook, NSW DPI Tamworth

Figure 12. 2,4-D applied at the 4-8 leaf stage. Image: T. Cook

Table 3: Control of 4 to 8 leaf wild radish using herbicides with different modes-of-action, Nyngan 2014

Treatment (rateha)	Rate (/ha)	Mode-of-action	Wild radish control (%)
untreated		----	0
2,4-D amicide (625 g/L) (<4 leaf)	800 mL	I	100
2,4-D amine (625 g/L) (4-8 leaf)	800 mL	I	81
chlorsulfuron (750 g/L)	20 g	B	79
pyrasulfotole + bromoxynil	1 L	H + C	100
pyrasulfotole + MCPA	1 L	H + I	100
diflufenican (200 g/L)	200 mL	F	98
bromoxynil (200 g/L)	1 L	C	50#
glyphosate (690 g/kg)	0.9 kg	M	57*
atrazine (900 g/kg)	1.1 kg	C	85
metribuzin (480 g/kg)	580 mL	C	34
isoxaflutole (700 g/kg)	100 g	H	81
carfentrazone ethyl + glyphosate (450 g/L)	60 mL + 1.38 L	G + M	49*
MCPA + bromoxynil + diflufenican	1 L	I + C + F	100
MCPA LVE (500 g/L)	1 L	I	100
imazethapyr (700 g/kg)	70 g	B	84
MCPA LVE (500 g/L) + diuron (900 g/kg)	1 L + 280 g	I + C	100

* *Note that these are seedlings that emerged after glyphosate application. Wild radish control with glyphosate for emerged plants was 100%.*

 # Half the recommended rate and applied too late.

Although herbicide rotation is clearly an easy choice to make and can maintain high levels of control in the short to medium term, farmers must also adopt additional strategies like manuring, fallow and weed seed collection at harvest to protect current herbicides. As we have seen, reliance on rotation of herbicide chemistry leads to resistance to multiple modes of action.

Figure 13. Pyrasulfotole + MCPA applied at the 4-8 leaf stage. Image: T.Cook

Over the past few years the amount of information to help you get better value from your herbicides by improving coverage and keeping it in your paddock has exploded.

Everyone should note that in 2008 'Labelled' Spray Drift Regulations were introduced by the Agricultural Products & Veterinary Medicines Authority (APVMA). These include:

- Required Spray Qualities –medium, coarse, very coarse, extremely coarse
- Defined Wind Speed Ranges
- No-spray zones / down-wind buffer distances
- Additional Record Keeping - Federal Requirement

There is also currently a review of national spray drift guidelines by the National Working Party on Pesticide Application (NWPPA - www.nwppa.net.au) to seek changes to regulations and labels. As better spray technology is adopted it is hoped that down-wind buffers and other regulations can be modified.

The GRDC has taken better spray application very seriously by funding the "Better Spray Application" series of workshops across Australia (GRDC project: BGC0002) which has trained over 4070 growers and advisers in 170 workshops across Australia since 2013.

Plenty of information is available to help you make the best spray decisions. Here are some links:

GRDC

Bill Gordon Consulting

Canadian 'Spray King' Tom Wolfe's (AKA @ Nozzle_guy) Sprayers 101

Figure 14. Nozzle selection was a major component of the National Better Spray Application Project. Image: P. Crook.

THE USA HAS NOW AGREED ON A DEFINITION FOR "SUPERWEED"

SUPERWEED!

With the explosion in use of the term "SUPERWEED" in the popular and scientific press it has become necessary for the Weed Science Society of America (WSSA) to agree on the 'official' definition.

This is largely seen as a response to burgeoning glyphosate and multiple resistant weed populations in North America in particular.

Superweed | noun| *Slang (sic) used to describe a weed that has evolved characteristics that make it more difficult to manage due to repeated use of the same management tactic. Over-dependence on a single tactic as opposed to using diverse approaches can lead to such adaptations.*

The most common use of the term refers to a weed that has become resistant to one or more herbicide modes of action (http://www.croplife.org.au/downloadpdf.php?url=wp-content/uploads/2013/05/2014-Herbicide-MOA-Table.pdf) due to their repeated use in the absence of more diverse control measures. Dependence on a single mechanical, biological, or cultural management tactic has led to similar adaptations (e.g. hand-weeded barnyard grass mimicking rice morphology, skeleton weed rust only killing one biotype leaving the others to fill in the gaps).

Two common misconceptions about a superweed are that they are the result of gene transfer from genetically altered crops and that they have superior competitive characteristics. Both of these misunderstandings have been addressed by the Weed Science Society of America (WSSA) at http://wssa.net/2015/05/superweeds-common-fallacies-and-an-interesting-study/.

Adapted from: WSSA Newsletter Volume 43, No. 2 April, 2015

Figure 15. Glyphosate resistant Palmer amaranth in the USA. Image: D. Thornby.

Going on this definition, Australia is full of "superweeds" – Ed.

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