the northern
HERBICIDE RESISTANCE Reporter

A Newsletter keeping you up to date with research and development in herbicide resistance in the Northern Region

Glyphosate resistant weed population found on roadside

The following article is an adaptation of a press release released by the Australian Glyphosate Sustainability Working Group (23rd June 2010).

Glyphosate resistant annual ryegrass has recently been confirmed along several kilometres of roadside in semi-rural South Australia. This roadside, like much of Australia's 810,000 kilometres of roads, has a 20 year history of using glyphosate alone for weed control.

This is the first recorded case in Australia of a weed becoming resistant to glyphosate due to roadside management practices and is a highly significant discovery. The infestation was first observed in 2008 and seed was collected and tested for resistance at the University of Adelaide.

"Although the South Australian infestation was first noticed in 2008 it had clearly been there for some time for it to have spread so far" said Associate Professor Chris Preston, Chair of the Australian Glyphosate Sustainability Working Group. "Roadsides are routinely treated with glyphosate herbicide alone with few other effective weed control techniques being used, which should be ringing alarm bells with roadside managers".

Chris Preston says authorities, councils and communities must start looking at a range of roadside weed management techniques to prevent the development and spread of glyphosate resistant weeds along roadsides and movement into other sectors of the community.

Chris Preston believes more planning needs to go into roadside vegetation management to prevent the development of glyphosate resistant weeds, while meeting road safety requirements.

"Preventing the seed set of those weeds surviving the herbicide application is critical to the management of herbicide resistance," stated Chris Preston. "This applies as much to roadside weed management as it does in farming."

Anyone suspecting glyphosate resistant weeds should contact their state expert with details available from the Australian Glyphosate Sustainability Working Group web site **http://www.glyphosateresistance.org.au/suspect%20glyphosate.htm**

The Australian Glyphosate Sustainability Working Group has a web site with information about glyphosate resistance including a register of glyphosate resistant weed populations as well as guides and links for management of glyphosate resistance in different industries. **Go to: www.glyphosateresistance.org.au for more information.**

In this Issue ...

RESISTANCE is FUTILE

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Rotations using broadleaved crops assist feathertop Rhodes grass management

Vikki Osten

The inclusion of broadleaf crops during either winter or summer in central Queensland crop rotations can have a positive impact on the management of feathertop Rhodes grass (FTR). Broad-leaved crops, such as winter and summer pulses, sunflower and cotton, allow the use of grass selective post-emergent herbicides and, when used in conjunction with crop competition, can effectively limit FTR seed production.

The CQ long-term FTR management trial, located at Biloela Research Station, is investigating the impact of crop rotation on weed numbers. It has shown that pulse crops in winter or summer and/or sunflower in summer/autumn drive the FTR seed bank down. Since the start of the first winter phase in 2008 we have been tracking FTR survivors and seed production in each treatment (crop x management regime) over time. By doing this we have determined which crops and regimes (in rotation) are having the greatest impact on suppressing FTR emergence but also reducing the seed bank.

Feathertop Rhodes grass is best controlled when young and not stressed

Winter crop phase – chickpea

At the beginning of winter 2008, the potential FTR density across the trial site was approximately 500 plants per m² under a peak flush condition.

By the end of chickpea harvest in 2008, the treatments that kept FTR numbers lowest throughout the season were:

- pre-emergent herbicides applied to narrow-row crops
- pre-emergent herbicides with inter-row tillage in wide-row crops
- pre-emergent herbicides plus post-emergent Group A herbicide in the wide-row crops.

Generally the wide-row crop facilitated better in-crop FTR management, providing more space to apply the inter-row treatments with the open crop canopy allowing herbicide to reach the target.

Summer crop phase – mungbean and sunflower

During the 2009 summer crop phase, FTR management was substantially better in mungbean compared to sorghum.

By the end of the season the number of FTR plants in mungbean treatments was less than half that recorded in the best of the sorghum treatments. The mungbean strategy was using:

- pre-emergent herbicide at planting followed by a post-emergent Group A herbicide.

These treatments in mungbean significantly reduced FTR numbers over the season irrespective of the starting FTR densities, although Group A herbicides did differ slightly in their efficacy.

The 2010 summer crop phase included mungbean and sunflower and the FTR management regimes of a residual herbicide at planting, followed up with an in-crop grass selective herbicide. These treatments resulted in minimal FTR escapes and survivors and thus the seed bank was not replenished during the season. In comparison, control of FTR in sorghum was not as good as achieved within the broadleaved crops, even with the applications of knockdown herbicide through shields fitted with WeedSeeker technology.

Integrated weed management

A number of residual herbicides are registered for application at planting of mungbean, sunflower, cotton and chickpea. The FTR escapes can then be targeted post-emergence with the grass selective herbicides. Using these herbicides early in the crop's life, and while the FTR is small, will ensure the competitive advantage to these broadleaf crops. Once canopy closure occurs, few FTR plants should remain and those that do will have minimal seed-set.

Conclusion

If your FTR densities are moderate to high, or on the rise, it is worth considering the inclusion of a pulse crop, sunflower or cotton to allow the use of effective residuals and grass selective herbicides. Use of these tactics will rotate mode of action groups and thereby reduce the risk for development of glyphosate resistance in our summer grasses.

Commonly used terms

To increase the value and readability of the Reporter, we have included in this edition purple feature boxes which explain some terms commonly used in the Reporter. Keep an eye out for these purple boxes and please contact one of the editors if you have any questions in relation to the explanations provided.

Double knocking glyphosate resistant barnyard grass

Luke Boucher

Field studies on glyphosate resistant barnyard grass by NSW Industry & Investment indicated that:

- the double knock tactic could be effective in controlling resistant biotypes and
- a high rate of glyphosate applied alone to small (2-3 leaf) resistant plants could still provide adequate control.

However, results from these studies were complicated by subsequent flushes of emergence, giving several weed growth stages at treatment and assessment.

Two pot experiments were conducted in a greenhouse during the 2008/09 and 2009/10 summers to test the efficacy of the double knock tactic (glyphosate followed by paraquat) and to assess the level of control with glyphosate and paraquat alone.

The herbicide treatments were:

- early and late applications of high and low rates of glyphosate
- early and late applications of high and low rates of paraquat
- double knock treatments with different rates of glyphosate and paraquat.

These were applied to a glyphosate-resistant biotype from Bellata (NSW) and a glyphosate-susceptible biotype from Dalby (QLD). The experiment in 2009/10 had some additional treatments including extra rates and timings of the single glyphosate and paraquat applications ***(Table 1).*** Weeds had 2 tillers at the time of early application and >6 tillers at late applications.

Treatment rates lower than field recommended rates were applied in both experiments as plants were grown in ideal conditions and therefore more susceptible to herbicides.

Increased tillering is a typical response in both glyphosate-resistant and -susceptible barnyard grass after surviving treatment with glyphosate

Glyphosate applied alone did not control the resistant plants (≤ 50%) and surviving plants went on to produce 2000-4000 seeds ***(Table 1).***

The level of control of the susceptible biotype differed with weed size and glyphosate rate. Only when the higher rate (0.7 L) of glyphosate was applied to smaller, susceptible barnyard grass was 100% control achieved. However, when this treatment was applied 1 week later to larger susceptible plants, control was reduced to 90%. Therefore, a robust rate of glyphosate can be used to achieve good control of young, susceptible barnyard grass, but can not be relied on for effective control of either more mature or glyphosate-resistant barnyard grass, even when young.

Paraquat applied alone provided 100% control of young glyphosate-resistant and -susceptible plants at either rate (1 or 2 L/ha). The control was reduced to 50-90% when applied to bigger barnyard grass at the lower rate. The higher rate provided full control of older plants. Paraquat is a viable alternative to glyphosate for the control of glyphosate-susceptible barnyard grass and a useful option for controlling glyphosate-resistant plants. However, robust rates should be applied for maximum efficacy particularly for tillering plants.

The double knock treatments achieved 100% control of both resistant and susceptible biotypes irrespective of glyphosate and paraquat rates (*Table 1).* The double-knock tactic was effective in stopping seed set which is vitally important in reducing the risk of glyphosate resistance and weed population density.

Knockdown treatments have also been tested on field populations of both glyphosate-resistant and -susceptible barnyard grass. Results have shown that the double-knock tactic is the only tactic that consistently provided effective control across environments. Results from field testing will be included in future editions of the reporter.

Table 1. Efficacy (% control and seed production on survivors) of knockdown herbicides (46 days after second knock) on resistant (R) and susceptible (S) barnyard grass populations from two trials (2009 and 2010). The first knock (K1) was applied at the 2 tiller stage (early), and second knock (K2) was applied 7 days later when plants had >6 tillers (late). Seed production data are an average of 2009 and 2010 results. (fb = followed by).

Herbicide and rate (L/ha)	Control (%)				Average seed production (#/plant)	
	R		S		R	S
	2009	2010	2009	2010		
Untreated	0	0	0	0	4050	2920
Glyphosate CT (0.35) early	**20**	**0**	**77**	**80**	**3940**	**3250**
Glyphosate CT (0.7) early	40	10	100	100	2520	0
Glyphosate CT (0.35) late	**50**	**0**	**70**	**0**	**3550**	**2190**
Glyphosate CT (0.7) late		0		90	1980	0
Paraquat (1.0) early		**100**		**100**	**0**	**0**
Paraquat (2.0) early		100		100	0	0
Paraquat (1.0) late	**50**	**90**	**90**	**90**	**1090**	**490**
Paraquat (2.0) late		100		100	0	0
Glyphosate CT (0.35) K1 fb Paraquat (1.0) K2	**100**	**100**	**100**	**100**	**0**	**0**
Glyphosate CT (0.35) K1 fb Paraquat (2.0) K2	100	100	100	100	0	0
Glyphosate CT (0.7) K1 fb Paraquat (1.0) K2	**100**	**100**	**100**	**100**	**0**	**0**
Glyphosate CT (0.7) K1 fb Paraquat (2.0) K2	100	100	100	100	0	0

Managing glyphosate resistant summer grasses

Jeff Werth

Summer grasses are among the weed species with the highest potential to develop resistance to glyphosate. There are now a number of populations of barnyard and liverseed grass resistant to glyphosate in Queensland and New South Wales.

There are a number of reasons for this:

- Reliance on glyphosate for the majority of grass control
- Limited options for fallow control other than glyphosate
- Limited post-emergent options for control in crop
- High seed production
- Usually present in the field in high densities

The numbers of suspected cases of resistant populations of barnyard and liverseed grass increase each year. There are also several populations of liverseed grass that are resistant to atrazine *(group C)*.

Feathertop Rhodes grass is another species that is becoming more common under farming systems reliant upon glyphosate. It is a widespread problem in central Queensland, and is now spreading to northern New South Wales.

"Opportunity" weed management

It is important that the herbicide mode of action group (MOA) is considered when controlling weeds. Using one MOA continuously will ultimately lead to the development of herbicide resistance. Therefore becoming familiar with what MOA group a herbicide comes from will enable more effective long term weed control.

Different crops allow different weed management tactics to be used; these can be either by different MOA's or non-herbicide options. This creates "opportunities" to implement an Integrated Weed Management (IWM) system using a range of both herbicide and non-herbicide options.

The term "opportunity cropping" is used for crop rotations that aren't "locked in" and depend on availability of moisture. This idea can also be applied to IWM, so that no single weed control tactic is overused.

Rotating herbicide MOA's

There are a number of different herbicide MOA's that can be used on summer grasses, as outlined in *Table 1.* The number and type of registered MOA's differ with each crop. For example, cotton has 5 MOA groups which can be used on grasses, whereas sorghum allows only two.

Using non-herbicide options

The pressure on herbicides to provide the majority of weed control can be reduced by utilising non-herbicide options where possible. This can be done in a number of ways including altering planting times, encouraging crop competition, cultivation, chipping and spot spraying. These can also be used in conjunction with herbicides to enable them to be more effective. Possible non-herbicide options and how they can be used are listed in *Table 2.*

Important points for herbicides

- **Paraquat and paraquat + diquat are best applied with higher water volumes, as it is essential to get good coverage on weeds. These are most effective on small grasses.**
- Barnyard grass control can be variable with atrazine, prometryn and fluometuron.
- **Imazapic, Imazamox and Imazethapyr have long plant backs to a range of crops (see label).**
- Atrazine has a long plant back to cotton (see label).

Table 1. Registered herbicide options (other than glyphosate) for controlling Barnyard (BG), Liverseed (LG) and Feathertop Rhodes (FTR) grass in crop and fallow

Tactic	MOA	Active	Product	Fallow	Cotton	Sorghum	Sunflowers	Soybeans	Maize	Mungbeans
Pre-plant / Fallow knockdown herbicides	L	Paraquat		BG LG						
	L	**Paraquat+ Diquat**	**Spray.Seed®**	**BG LG**						
	L+Q	Paraquat+ Amitrole	Alliance®	BG						
Pre-emergent herbicides	**B**	**Imazapic**	**Flame®**	**BG LG**						
	B	Imazethapyr	Spinnaker®					BG		BG
	C	**Atrazine**				**BG**			**BG**	
	C	Diuron			BG					
	C	**Prometryn**			**BG**					
	C	Fluometuron			BG LG					
	C	**Fluometuron+ prometryn**	**Convoy**		**BG LG**					
	D	Trifluralin			BG LG		BG LG	BG LG		BG LG
	D	**Pendimethalin**	**Stomp®**		**BG LG**		**BG LG**	**BG LG**	**BG LG**	**BG LG**
	D	Chlorthal-dimethyl	Dacthal®		BG LG					
	F	**Norflurazon**	**Zoliar®**		**BG**					
	J	EPTC	Eptam®				BG		BG	
	K	**Metolachlor**			**BG LG**	**BG LG**	**BG LG**	**BG LG**	**BG LG**	**BG LG**
	K	Propachlor	Ramrod®			BG LG			BG LG	
	C+K	**Atrazine+ Metolachlor**	**Primextra Gold®**			**BG LG**			**BG LG**	
Mid-season residual herbicides	C	Fluometuron			BG LG					
	C	**Prometryn**			**BG**					
	C	Fluometuron+ prometryn	Convoy		BG LG					
Post-emergent selective herbicides	**A**	**Haloxyfop**	**Verdict™**		**BG LG**		**BG LG**	**BG LG**		**BG LG**
	A	Clethodim	Sequence®		BG LG FTR			BG LG FTR		BG LG FTR
	A	**Butroxydim**	**Factor™**		**BG LG FTR**		**BG LG FTR**	**BG LG FTR**		**BG LG FTR**
	A	Sethoxydim	Sertin®		BG LG		BG LG	BG LG		
	A	**Fluazifop**	**Fusilade™**		**BG LG**		**BG LG**			
	A	Propaquizafop	Correct®		BG LG		BG LG			
	A	**Quizalofop**	**Leopard®**				**BG LG**	**BG LG**		**BG LG**
	B	Imazamox	Raptor®					BG LG		BG LG
	B	**Imazethapyr**	**Spinnaker®**					**BG**		
	C	Atrazine				BG			BG	

Strategic Integrated Weed Management

- **Know the key weed species in each field.**
- Know the history of herbicide use in each field. If glyphosate has been predominately used, it is time to change.
- **Know what herbicides are effective on key weeds and aim for optimum control.**
- Rotate between herbicide groups.
- **Use a selection of non-herbicide control options whenever the opportunity arises.**
- Ensure survivors do not seed and replenish the soil seed bank.
- **Avoid introduction or spread of weeds by contaminated seed, grain, hay or machinery.**
- Manage weeds in surrounding non-crop areas.
- **Review the control achieved, and adjust future management strategies accordingly.**

For further information

- **Integrated Weed Management in Australian cropping systems – a training resource for farm advisers. CRC for Australian Weed Management, Adelaide, South Australia.**
- **WEEDpak**

Glyphosate resistant barnyard grass on a property in southern Queensland

Field capacity

The amount of moisture that a soil can hold immediately after all free-draining water has been lost. Effectively this is the full load of water a soil holds.

Table 2: Non-herbicide options for reducing the impact of summer grasses in crop and fallow.

Option		Crops	Comments
Time of planting	**Delayed planting of summer crops**	Sorghum Maize Soybeans Mungbeans	The major flushes for barnyard grass and liverseed grass occur late spring/early summer. Delayed sowing until after these flushes emerge allows other weed control options to be used such as double knock and full disturbance planting. Some summer crops grow slowly in cool spring conditions and therefore don't compete well with weeds. Delayed planting until conditions are warmer will help increase the crops competitiveness.
	Early planting of winter crops		Winter crops that aren't harvested until November/December may have summer grasses that have already germinated. When harvesting has been completed, these grasses may have passed their optimum time to be sprayed. Choosing crops/varieties that can be planted earlier or are faster to mature in order to be harvested before summer grass emergences enables them to be controlled when they are small.
Crop competition	**Crop and variety choice**	Sorghum	Some crops and varieties are more competitive against weeds. Crops such as sunflowers have a low competitive ability and therefore are preferably not planted into fields with a heavy summer grass or broadleaf infestation. An evenly established, vigorously growing crop can compete strongly with weeds.
	Row spacing and plant population	Sorghum Maize Soybeans Mungbeans	Decreasing row spacing creates less favourable conditions for competing weeds by increasing competition for moisture and light. Wider rows favour weed growth but allow inter-row cultivation.
	Weed-free periods	Cotton Sorghum Maize Soybeans Mungbeans	Keeping crops weed-free while they are getting established allows the crop to get a head start with all resources available. Once established it can then out compete weeds by shading, and taking resources with a larger root system.
Cultivation	**Full-disturbance planting**		For high weed pressure situations at the time of planting, using equipment that creates a full disturbance to kill weeds while planting is an option that reduces the reliance on herbicides.
	Strategic		Cultivation of major flushes either before planting, in fallow or inter-row can significantly lessen the selection pressure on potential herbicide resistant weeds.
	Inter-row	Cotton Sorghum Sunflowers	Inter-row cultivation can effectively control small weeds at a reasonable cost and should be considered for seedling or salvage control.
	Salvage		Last resort for weeds out of control. Needs to be done before weeds have set seed or damage is already done. Inversion can be beneficial for small seeded species.
Chipping and spot spraying		All	Can be a very effective method to control survivors of herbicide application, particularly if they occur in low densities. Effectiveness is reliant upon good scouting to ensure escapes do not set seed.

Group A herbicide in-crop options for the control of glyphosate resistant barnyard grass

Bill Davidson and Tony Cook

The recent development of Group A and M multiple resistant annual ryegrass serves as a stark reminder that persistent use of any herbicide mode of action group can cause resistance.

After the discovery that clethodim products (Group A) controlled large glyphosate resistant ryegrass plants, this herbicide was used repeatedly as an alternative to glyphosate. It is estimated that low level clethodim resistance developed within only 5 to 7 years after this practice began.

With the increasing number of glyphosate resistant barnyard grass populations, land managers are looking at alternative options, such as Group A herbicides in-crop, to control these weeds. Considering the impact this practice had on annual ryegrass, we should be concerned about using Group A herbicides on glyphosate resistant barnyard grass.

Whilst Group A herbicides can be a highly effective tool for the control of this weed, they need to be used strategically along with other weed control tactics to prevent the onset of Group A resistance.

To test which Group A herbicides are most effective on glyphosate resistant barnyard grass, two experiments were conducted; a glasshouse pot experiment at Tamworth Agricultural Institute and a field trial in a paddock at Bellata, north west NSW.

Glasshouse experiment

A range of Group A herbicides registered for use in broad-leaf crops were applied to glyphosate resistant barnyard grass grown under stress-free conditions in a glasshouse. The purpose of this experiment was to determine the best Group A treatments for the control of glyphosate resistant barnyard grass, when treated at the mid to late tillering growth stage.

Total control of glyphosate resistant awnless barnyard grass achieved using Verdict™ 520 at 150mL/ha in pot trial

Verdict™ 520, Factor™ WG and Fusilade™ were the best treatments (both low and high rates) while other treatments achieved very high levels of control (>89%) but some plants survived ***(Table 1).*** The results presented here indicate that that lower rates of Sertin® and Select® were marginally acceptable for control.

High levels of control are common in glasshouse based research as plants are more susceptible to herbicides. This could be due to increased growth rates and leaf surfaces that have a thinner layer of wax *(increased herbicide uptake).* Therefore, a field based experiment using identical treatments should be more representative of herbicide efficacy.

Table 1. Efficacy (% control) of Group A herbicide treatments for the control of glasshouse grown glyphosate resistant barnyard grass, assessed 33 days after treatment.

Herbicide	Rate (per ha)	Control (%)
Verdict™ 520	150mL	100
Verdict™ 520	75mL	100
Factor™ WG	180g	100
Factor™ WG	90g	100
Fusilade™	1L	100
Fusilade™	500mL	100
Select®	375mL	99.7
Select®	187mL	89.3
Sertin® 186	1L	97.3
Sertin® 186	500mL	94.7

Wilting point

The level of moisture in the soil at which a plants leaves start to droop. Wilting point differs between soil types and plant species: some soils 'hold' moisture more tightly, and some plants are better than others at getting moisture out of relatively dry soils.

Table 2. The most effective Group A herbicide treatments for field grown glyphosate resistant barnyard grass control, assessed 23 days after treatment. The other treatments achieved 69-89% control.

Herbicide	Rate (per ha)	Control (%)
Verdict™ 520	150mL	100
Verdict™ 520	75mL	95
Factor™ WG	180g	100
Factor™ WG	90g	98
Sertin® 186EC	1L	100
Fusilade™	1L	98
Select®	375mL	96

Field Trial

The purpose of this experiment was to confirm which Group A herbicides provide satisfactory control of glyphosate resistant barnyard grass under field conditions, and to compare results with those obtained from the glasshouse experiment.

Verdict™ 520 and Factor™ WG at both rates, and Sertin® 186, Fusilade™ and Select® at the higher rates were all highly effective with 95-100% control ***(Table 2).*** The lower rates of Sertin® 186 and Select® resulted in lower efficacy (69 - 89%). These results agree with those from the glasshouse experiment.

In addition, a range of in-crop (wheat) grass herbicides were tested to determine if these could have a role to manage glyphosate resistant barnyard grass in late winter cereals. One herbicide was very effective but it is unlikely to be recommended as pre-harvest withholding periods are likely to be breached. Results are not shown as the products tested are not registered for control of awnless barnyard grass.

Caution!

The presence of glyphosate resistant barnyard grass is likely to lead to the increased use of Group A herbicides for its control. Our results show that there are some very effective Group A herbicides available to control glyphosate resistant barnyard grass. However, from previous experience it is known that continuously using herbicides from a single mode of action group is likely to result in multiple resistance to very effective herbicide groups including A and M.

To reduce the risk of resistance, the aim should be to apply these herbicides to as few plants as possible, thereby reducing selection pressure. To do this, the application of highly effective pre-crop control tactics is vital. The judicious use of control tactics such as double knocking, residual herbicides and occasional strategic cultivation should reduce plant numbers in crop. There is a range of effective pre-emergence herbicides that can be used in-crop to prevent plants establishing. Undertaking these treatments prior to applying Group A herbicides will dramatically reduce the selection pressure due to reducing plant numbers.

Untreated glyphosate resistant awnless barnyard grass in the field trial

It is also important to control seed set on any survivors. Each herbicide application should be followed with a different tactic *(eg. hand chipping)* or herbicide from a different mode of action group *(eg inter-row Group L)* to delay the onset of resistance.

Presently, the herbicides tested in our study are generally registered in summer crops such as cotton, soybeans, mung beans, sunflowers, peanuts, navy beans and in lucerne. However, the use of these herbicides in fallows is not recommended as there is no label registration for this situation. Always follow registration information as provided on herbicide labels.

Fitness penalty

Rare genes that provide some particular benefit to a plant (such as herbicide resistance) often come with a price. The genes may be rare because plants that have that gene do not grow and reproduce as well as plants that don't have the same gene. We call the amount of reduction in reproductive success (number of seeds produced per plant) a fitness penalty. Some herbicide resistant populations have been found to have around 30% fitness penalty – but others have been found not to have any penalty at all.

Costs and risk levels of glyphosate-reliant cotton farming systems in Australia

David Thornby, James Hill and Jeff Werth

Dealing with the issue of glyphosate resistance implies two potential strategies: taking action to prevent resistance, or taking action to manage resistant populations once they occur. Both approaches are feasible in a broad sense, but in practice both incur extra costs compared to strategies that rely mainly or totally on glyphosate.

'Insurance' choices must be made between choosing to pay extra now to reduce resistance risk, and choosing to pay less now but more later when or if resistance occurs.

In this article, we discuss some simple weed control scenarios based around two possible strategies.

- The 'no prevention' system in which glyphosate is used exclusively in a herbicide tolerant cropping system until resistance occurs, at which point non-glyphosate management options are added to the system.
- The 'prevention' system in which an integrated weed management (IWM) strategy including both glyphosate and other methods of killing weeds is used to stop resistance occurring.

We used DEEDI's online glyphosate resistance risk assessment tool to analyse the effectiveness (or value) of preventive measures, and a simple economic framework to compare the costs of each system.

Scenarios of weed control in Roundup Ready Flex® cotton

The three scenarios presented in Table 1 have different summer weed control strategies. Winter strategies are assumed to be the same for each scenario. The summer strategies outlined are assumed to be used in both fallow and in crop, for simplicity.

In our analysis we tested these scenarios in a simplified continuous dryland cotton rotation of one crop every two years.

We assumed that glyphosate resistance occurs in scenario 1 after 15 years, at which point control methods switch from 1a to 1b *(see Table 1)*. In scenario 2 we assumed that resistance is prevented throughout the length of the scenario, meaning that the tactics remain unchanged.

Scenario economics

We calculated total weed management costs per season for each scenario based on the number of applications of each control tactic assumed in *Table 1.* We then used this information to calculate costs for 40-year scenarios. Over 40 years, the 'prevention' scenario cost approximately two thirds the price of the 'no-prevention' scenario ($6760 vs. $9925/ha respectively).

Scenario risk assessments

DEEDI's online risk assessment tool uses a scoring method to determine the resistance risk rating of:

- weed species being managed in a given paddock, and
- the crop and fallow phases in the rotation for that paddock.

Risk ratings for phases in the rotation range from zero to five, with any score of three or above considered very high risk. For weed species risk, any score above 50 would be considered to indicate high risk.

Scores for each scenario with a range of high and low risk grass weeds are shown in *Tables 2 and 3. Figure 1* shows how the tool presents scores to the user.

Table 1. Summer weed control strategies used in three resistance risk scenarios

Control method applications	Number of cost/ha ($) per season	Base cost/ha ($)	Total
Scenario 1a: Continuous Roundup Ready Flex® cropping with glyphosate alone (no prevention)			
Roundup Ready Herbicide® (RRH)	3	30	90
TOTAL/ha			90
Scenario 1b: RRFlex after resistance has evolved			
Cultivation	2	19	38
Pre emergent herbicide	1	30	30
RRH	3	30	90
Selective herbicide	1	35	35
Lay-by	1	50	50
Chipping	1	100	100
TOTAL/ha			343
Scenario 2: IWM for resistance prevention			
Cultivation	1	19	19
Pre emergent herbicide	1	30	30
RRH	2	30	60
Selective herbicide	0	35	0
Over the top alternative herbicide	0	45	0
Lay-by	1	50	50
Chipping	0.1 ha	100	10
TOTAL/ha			169

Table 2. Average glyphosate resistance risk ratings as calculated by the risk assessment tool for control methods in three management scenarios

Scenario	Risk rating
1a	2.9
1b	0
2	0

The 'prevention' scenario clearly has a lower cost over 40 years than the 'no-prevention' scenario. While this relies on a number of assumptions, including the relative cost of control measures over time and the time it takes to reach resistance, this simple analysis demonstrates that doing nothing is likely to have a long-term cost.

Figure 1. Glyphosate resistance risk ratings for weeds (above) and crop phases (below) for the 'no-prevention' scenario (1a) as calculated by DEEDI's online risk assessment tool.

Table 3. Total glyphosate resistance risk ratings for three grass weeds under three management scenarios calculated by the risk assessment tool

Weed risk ratings			
Scenario	Barnyard grass	Liverseed grass	Johnsongrass
1a	53.7	56.6	29.0
1b	0	0	0
2	0	0	0

Risk assessment using the online tool shows two important outcomes. First, both strategies that use a range of tactics *(1b and 2)* are very low risk *(Table 2)*. Secondly, high risk management results in varied levels of resistance risk for individual weeds. The grasses tested in these scenarios show a range of overall risk levels *(Table 3)*, though all have high to very high levels of risk for glyphosate resistance. Growers can use the risk assessment tool to help them understand which species on their own farms are at high risk of glyphosate resistance, and can then concentrate on dealing with these high risk species when planning a preventive strategy.

DEEDI's online glyphosate resistance toolkit can be found at www.deedi.qld.gov.au.

For further information, contact David Thornby by email: david.thornby@deedi.qld.gov.au, or phone 07 46398811.

Fold

A term for how resistant a weed population is to a particular herbicide. The effective rate of a herbicide on a weed population is often tested as the dose required to kill 50% of plants treated with a herbicide. If a resistant population takes twice the rate of herbicide to kill 50% of plants than a 'normal' population, it is said to have two-fold resistance. If a population takes ten times the rate to kill 50% of plants compared to a 'normal' population, it is said to have ten-fold resistance. Even quite weak resistance (three- to four-fold resistance) can make it impossible to gain reliable control with a herbicide.

GRDC has funded an Australian Herbicide Resistance Initiative

The AHRI team based at The University of Western Australia in Perth, lead by Professor Steve Powles (centre - in white shirt)

WAHRI (Western Australia Herbicide Resistance Initiative) has been refunded for 5 years with a new national role. The focus for the now named Australian Herbicide Resistance Initiative (AHRI) will continue to be on strategic and applied research aimed at minimising the adverse impacts of herbicide resistance and weed problems on Australian cropping.

To achieve this national focus, there will be collaboration with Department of Agriculture and Food in WA, DEEDI (formerly DPI&F) in Qld and the Universities of Melbourne and Adelaide.

The new research program extends from agronomic techniques for the management of crop weeds through to fundamental research on the molecular and genetic factors determining herbicide resistance evolution.

There will be five programs:

1. Resistance evolution

- Resistance surveys for ryegrass, wild oats, barley grass, brome grass, wild radish and fleabane
- Ongoing research on the importance of maintaining optimum herbicide efficacy
- Resistance evolution studies to predict the onset of resistance to new herbicides, ways to delay resistance onset and resistance management techniques

2. Resistance biochemistry

- Identify the P450 genes responsible for cross resistance to many herbicides in ryegrass
- Screening studies seeking to inhibit these P450 enzymes to overcome metabolism based resistance
- Identify the precise gene mutations endowing ALS and ACCase resistance and to develop molecular markers for their rapid identification

3. Resistance management

- The prevention/minimisation of seed production of cropping weeds
- The Harrington Seed Destructor (HSD) will be evaluated across a range of crop types, harvest scenarios and across several regions of Australia

4. Extension and communication

- Key messages delivered to agronomists, industry and growers through regional Crop Updates, field days, Integrated Weed Management (IWM) courses and grower and agronomist workshops
- A revamped AHRI website (www.ahri.uwa.edu.au)

5. National collaboration

The collaboration with our team at Toowoomba and Tamworth will involve a number of important resistance issues for the northern region.

This will include:

- research on the resistance mechanisms for our key resistant weeds including wild oats and fleabane
- survey for any Group I resistance in our Brassica weeds
- options for improved technology transfer
- testing of the HSD on northern weeds
- improved modelling of evolution and spread of resistance in northern weeds.

To subscribe to AHRI quarterly electronic newsletter, follow this link:

http://www.ahri.uwa.edu.au/Subscribe-to-Newsletter

Impact of weed age on efficacy of knockdowns for flaxleaf fleabane in fallows

Steve Walker

Snap shot

- **Herbicide efficacy was reduced markedly by spraying older weeds. The overall trend was an approximate 10% decrease in efficacy for each month increase in age.**
- As well, efficacy was affected by weed density and growing conditions, with lower efficacy on more dense infestations and stressed weeds.
- **Efficacy of some treatments was reduced with increasing weed age at spraying irrespective of better growing conditions and using higher rates, such as glyphosate + 24D and 24D followed by Spray.Seed®.**
- However, most double knock treatments were highly effective on 1 and 2 month old weeds, and remained effective on 3 month old weeds provided rates were increased and applied under good growing conditions. The consistently most effective treatment was glyphosate + Tordon™75D followed by Spray.Seed®.

The issue

Industry experience is that small fleabane in fallows are generally well controlled, although not completely, with the standard fallow mix of glyphosate plus 2,4-D, provided there is good spray coverage and it is applied under good growing conditions. For larger weeds, a number of glyphosate mixes and sequential applications with paraquat products *(known as double knock)* are used, although control is variable. This research investigated the impact of weed age on efficacy at sites heavily infested with fleabane in 2009 and 2010.

What we did

In both years we investigated the impact of different weed ages on the efficacy of registered herbicides for fleabane control compared with the industry standard for fallow broadleaf weed control of glyphosate + 24D. The field research was undertaken near Dalby in 2009 and near Warwick in 2010.

The 2009 site had a large infestation with over 250 seedlings per m2 emerging in May. The same herbicide treatments were applied when the weeds were:

- approximately 1 month old and predominantly small rosettes (<5cm diameter)
- at 2 months old when the weeds were a mix of small and large rosettes (>10cm diameter)
- at 3 months old when the weeds were large rosettes and beginning to elongate.

Glyphosate (CT 1.5L/ha) mixed with 2,4-D (Surpass® 475 1.0 L/ha) was compared with:

- glyphosate + Tordon™75D (0.7L/ha)

and four double knocks (sequential applications seven days apart) of:

- glyphosate + 24D followed by Spray.Seed® (2.0L/ha)
- glyphosate + 24D followed by Alliance® (2.0 L/ha)
- glyphosate + Tordon™75D followed by Spray.Seed®
- 2,4-D (Amicide® 625 1.5L/ha) alone followed by Spray.Seed®.

The 2010 site had a very dense infestation with approximately 540 seedlings per m2 emerging in March. The same herbicide treatments used in 2009 were applied to:

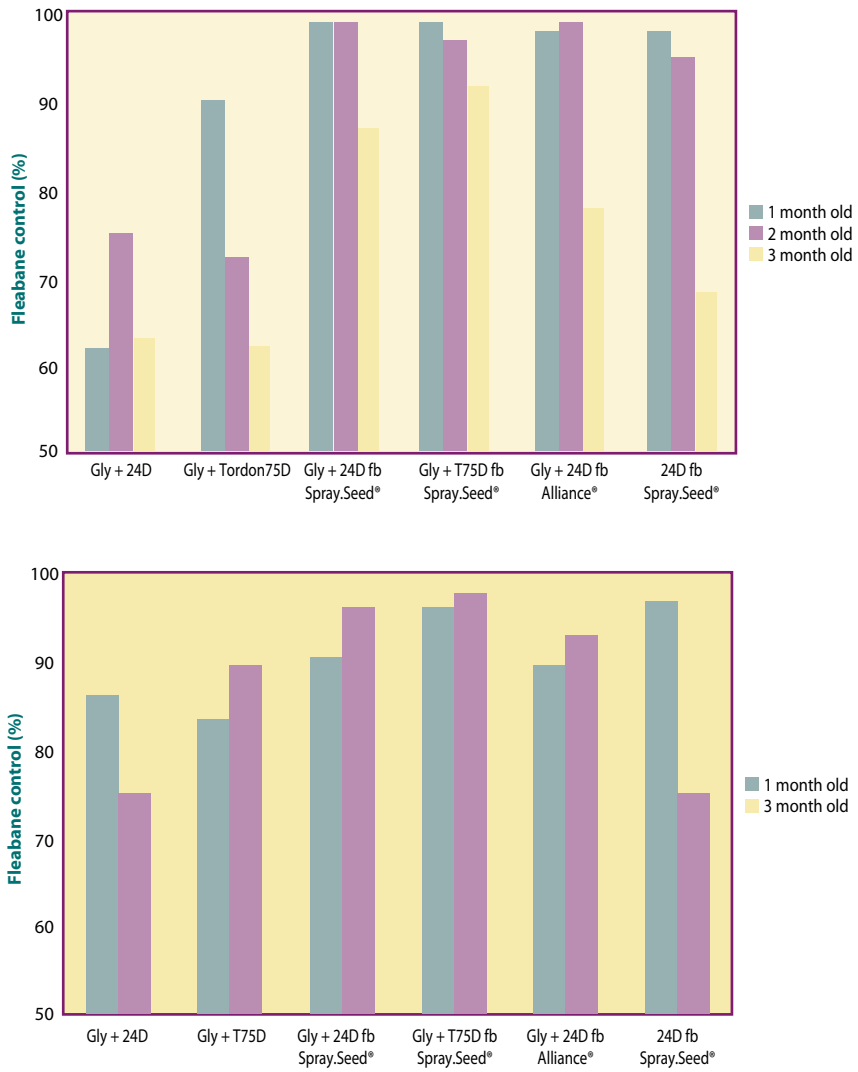
- approximately 1 month old and predominantly small rosettes (<5cm diameter) in April
- 3 months old weeds that were large rosettes and beginning to elongate in June.

However in this experiment, the treatment rates for the non-glyphosate products were increased as follows: 24D at 2.0L, Tordon™75D at 1.0L, Alliance®at 2.0L and Spray.Seed® at 2.4L/ha.

At the 2009 site, 73mm of rain was received for the 4 months following weed emergence, whereas 196mm was received for the same period at the 2010 site.

Poor control of elongating fleabane with Spray.Seed®. The product is more effective on small fleabane.

Figure 1. Control of fleabane (% of untreated) when sprayed in a fallow paddock at 3 different ages near Dalby in 2009 (top) or 2 ages near Warwick in 2010 (bottom). Same rates were used for each age in 2009 but increased for older weeds in 2010. Assessment was done approximately 6 weeks after the second knock was applied. Gly = Glyphosate CT; T75D = Tordon™75D; fb = followed by 7 days after first spraying



Key findings in 2009

Overall, the best herbicide treatments across all weed ages were the following double knocks:

- glyphosate + Tordon™75D followed by Spray.Seed® (96%)
- glyphosate + 2,4-D followed by Spray.Seed® (95%)
- glyphosate + 2,4-D followed by Alliance® (92%).

These were substantially better than the commonly used glyphosate + 2,4-D, which had an average of 67% control ***(Figure 1).***

Weed age had a large impact on herbicide efficacy, dropping from an average of 91% for 1 month old weeds to 75% for 3 month old weeds.

However, some herbicide treatments were less affected by weed age. Efficacy of glyphosate + Tordon™75D followed by Spray.Seed® was not significantly different irrespective of weed age, although there was a small trend towards less control with increasing age (99% to 92%).

Efficacy of the other double knock treatments was significantly reduced with increasing weed age, with the greatest reduction for 2,4-D alone followed by Spray.Seed® (98% to 68%).

Key findings in 2010

Very similarly to 2009, the best treatments over the 2 weed ages were the following double knocks:

- glyphosate + Tordon™75D followed by Spray.Seed® (98%)
- glyphosate + 2,4-D followed by Spray.Seed®(94%)
- glyphosate + 2,4-D followed by Alliance® (92%).

These were considerably better than commonly used glyphosate + 2,4-D with an average of 80% control (Figure 1). The knockdown with glyphosate + Tordon™ 75D was better with 87% control.

Many of the treatments applied to the young weeds were slightly less effective than in 2009. This was possibly due to the denser weed infestation in 2010 with over 500 seedlings per m2 compared to half that in 2009 experiment.

In contrast to 2009, efficacy of many of the 2010 treatments was not adversely affected by weed age. This was likely due to two factors – the more favourable growing conditions and higher rates used on the larger weeds in 2010.

Overall in both experiments, the consistently best treatment was glyphosate + Tordon™ 75D followed by Spray.Seed®.

Biomass

An amount of plant tissue produced during an experiment, measured by weight. Depending on the experiment, it could be whole-plant biomass, or biomass of the above-ground parts, or vegetative biomass (that is, not including seeds and flowers).

Editors

Michael Widderick (DEEDI)

Phone: 07 4639 8856

PO Box 2282 Toowoomba QLD 4350

Email: michael.widderick@deedi.qld.gov.au

Steve Walker (DEEDI)

Phone: 07 4639 8838

PO Box 2282 Toowoomba QLD 4350

Email: steve.walker@deedi.qld.gov.au

For further information contact

Tony Cook (Industry and Investment NSW)

Phone: 02 6763 1174

4 Marsden Park Road Calala NSW 2340

Email: tony.cook@industry.nsw.gov.au

Vikki Osten (DEEDI)

Phone: 07 4983 7406

LMB 6 Emerald QLD 4720

Email: vikki.osten@deedi.qld.gov.au

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