Resistance management strategies for glyphosate resistant weeds, finessing pre-emergent herbicides, and getting the early post-emergent space right

Christopher Preston[1], Jenna Malone[1], Patricia Adu-Yeboah[1], Michael Widderick[2], Navneet Aggarwal[3]

[1] University of Adelaide
[2] Queensland Government Department of Agriculture, Fisheries and Forestry
[3] South Australian Research and Development Institute

Key words

glyphosate resistance, pre-emergent herbicides, double knock

GRDC code

UOA2007-007RTX

Take home message

- Glyphosate resistance is increasing in incidence in Australia in both summer growing and winter growing weeds
- Management strategies that do not include glyphosate can be better than the double knock in managing glyphosate resistant populations
- Choosing the right pre-emergent herbicide strategy for the situation improves annual ryegrass control.

Glyphosate resistance

Recent weed resistance surveys are indicating an increase in glyphosate resistant weeds. This includes annual ryegrass, as well as summer growing weed species (Table 1). While the double knock has been the main management tactic for glyphosate resistant weeds it has sometimes been difficult to institute and other tactics, such as glyphosate mixtures, have been used instead. Management is further complicated by the evolution of paraquat resistance in both annual ryegrass and flaxleaf fleabane.

Table 1. Extent of resistance to glyphosate in various weed species collected in a random survey of cropping fields across Australia in 2020/2021. Samples were considered resistant if more than 20% of the individuals survived herbicide treatment. Annual ryegrass and common sowthistle were collected across Australia, while the other species were only collected in northern NSW and Queensland.

Weed species	Samples tested	Resistance to glyphosate (% of samples)
Annual ryegrass	1354	19
Common sowthistle	517	0.2
Flaxleaf fleabane	104	59
Feathertop Rhodes grass	128	97
Awnless barnyard grass	75	28
Sweet summer grass	26	58

The mechanism of resistance to glyphosate may also influence the results of management strategies. There are three main mechanisms of glyphosate resistance that have been identified in weeds in Australia: target site mutations; reduced glyphosate translocation through vacuolar sequestration; and gene amplification. Recently, it was found that applying glyphosate to glyphosate resistant barley grass increased the level of glyphosate resistance through increasing the number of copies of the EPSPS gene in the plants (Figure 1).

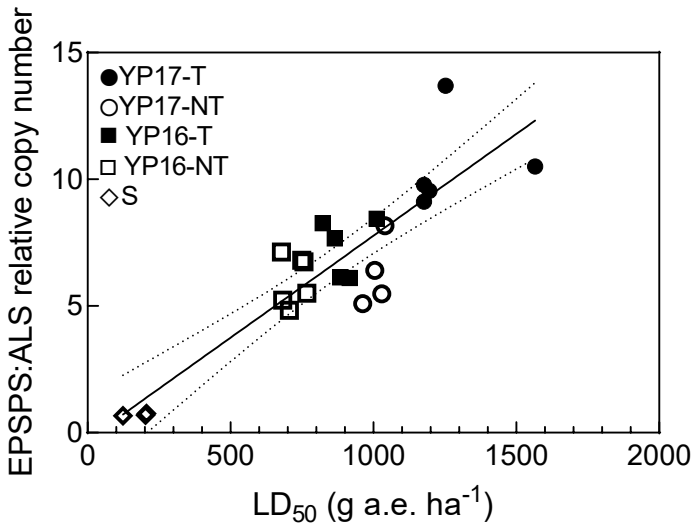

Figure 1. Increase of LD_{50} and EPSPS gene copy number in the progeny of glyphosate-resistant barley grass clones from 2 populations treated or not treated with glyphosate. Individual plants were divided into 2 clones. One clone from each individual was treated with 405 g ha^{-1} glyphosate and the other clone was untreated. Seed was collected from each clone. The LD_{50} was calculated from a dose response of progeny from each clone. The copy number of EPSPS for each set of progeny was determined by qPCR. Open symbols are progeny from clones not treated with glyphosate and closed symbols are progeny of clones treated with glyphosate.

This result suggests that management strategies using glyphosate will result in higher levels of resistance in weeds with the gene amplification mechanism. Other weeds with this resistance mechanism are windmill grass and brome grass. Flaxleaf fleabane, feathertop Rhodes grass, common sowthistle, barnyard grass and annual ryegrass all have populations with target site resistance and are likely to respond differently. Most glyphosate-resistant annual ryegrass plants have reduced translocation of glyphosate.

Managing glyphosate resistant weed populations

Experiments have been established exploring different management strategies on populations of glyphosate resistant weeds. Preliminary results for common sowthistle (Table 2) and feathertop Rhodes grass (Table 3) show that double knocks are better than using glyphosate alone; however, using herbicides other than glyphosate is better at keeping glyphosate resistant populations low. For barley grass, a double knock is better than glyphosate mixtures with Group 14 herbicides.

Table 2. Survival (%) of two glyphosate-resistant common sowthistle populations after herbicide treatment in the second year of the trial at Hermitage Research Facility, Warwick QLD. Populations containing 30% resistant individuals were sown and treated over 2 consecutive seasons with the same herbicide strategies.
fb = followed by.

Herbicide strategy	Survival (%)	
	ST white	ST yellow
Double knock alternative – 2,4-D fb paraquat + diquat (Spray.Seed®)	1.1	0
Double knock – glyphosate fb paraquat + diquat (Spray.Seed®)	0.1	0.6
Single knock – glyphosate applied morning	8	7
Single knock – glyphosate applied midday	20	13
Residual herbicide – Balance®	0	0

Table 3. Survival of feathertop Rhodes grass with different mutations in EPSPS after herbicide treatment in the second year of the trial at Hermitage Research Facility QLD. Populations containing 30% resistant individuals were sown and treated over 2 consecutive seasons with the same herbicide strategies. fb = followed by.

Herbicide strategy	Mutation		
	Pro 196 Leu	Pro 196 Ser	Pro 196 Thr
Double knock alternative – haloxyfop fb paraquat	16	55	0
Double knock – glyphosate fb paraquat	92	59	51
Single knock – glyphosate	80	54	71
Residual herbicide – s-metolachlor (Dual Gold®)	0	0	0

A challenge for the management of glyphosate and paraquat resistant annual ryegrass is that neither herbicide in the double knock will be effective on its own. An alternative approach to manage glyphosate resistant annual ryegrass when the seasonal conditions are appropriate is to dry sow and use pre-emergent herbicides and crop competition. However, with dry sowing it is important to choose the pre-emergent herbicides wisely. For dry sowing, more persistent herbicides are better than using less persistent herbicides, such as s-metolachlor + prosulfocarb (Boxer Gold®) (Table 4). Including an early post-emergent application of s-metolachlor + prosulfocarb (Boxer Gold), prosulfocarb (Arcade®) or aclonifen+diflufenican+pyroxasulfone (Mateno® Complete) can provide better control of annual ryegrass and provide insurance against poor control of weeds by pre-emergent herbicides due to seasonal conditions (Table 4).

Table 4. Annual ryegrass control in a dry sown wheat trial at Concordia, SA in 2023. Weed counts were made 49 days after sowing. fb = followed by, early post-emergent herbicide products applied 21 days after sowing.

Herbicide active(s)	Trade name	Formulation(s)	Rate(s)	Annual ryegrass (plants m^{-2})
Nil	Nil			76.8 a
Trifluralin	TriflurX®	480 g/L	2 L/ha	24.9 b
Pyroxasulfone	Sakura® Flow	480 g/L	210 mL/ha	13.2 bc
Prosulfocarb + S-metolachlor	Boxer Gold	800 g/L + 120 g/L	2.5 L/ha	37.6 ab
Cinmethylin	Luximax®	750 g/L	0.5 L/ha	15.2 bc
Aclonifen+ Pyroxasulfone+ Diflufenican	Mateno Complete	400 g/L 100 g/L 66 g/L	0.75 L/ha	24.0 b
Aclonifen+ Pyroxasulfone+ Diflufenican	Mateno Complete	400 g/L 100 g/L 66 g/L	1 L/ha	15.2 bc
Bixlozone	Overwatch®	400 g/L	1.25 L/ha	14.2 bc
Trifluralin fb (Aclonifen+ Pyroxasulfone+ Diflufenican)	TriflurX fb Mateno Complete	480 g/L fb (400 g/L 100 g/L 66 g/L)	2 L/ha fb 0.75 L/ha	14.7 bc
Trifluralin fb (Aclonifen+ Pyroxasulfone+ Diflufenican)	TriflurX fb Mateno Complete	480 g/L fb (400 g/L 100 g/L 66 g/L)	2 L/ha fb 1 L/ha	6.8 bc
Bixlozone fb (Aclonifen+ Pyroxasulfone+ Diflufenican)	Overwatch fb Mateno Complete	400 g/L fb (400 g/L 100 g/L 66 g/L)	1.25 L/ha fb 1 L/ha	0.5 c
Trifluralin fb (Prosulfocarb + S-metolachlor)	TriflurX fb Boxer Gold	480 g/L fb (800 g/L + 120 g/L)	2 L/ha fb 3 L/ha	8.3 bc
	P			0.0004

Getting better control of annual ryegrass with pre-emergent and early post-emergent herbicides

There are four main causes for pre-emergent herbicides to fail to control weeds: herbicide resistance in weeds; too little herbicide persistence; too much rainfall that moves the herbicide below the weed root zone; or too little rainfall to properly activate the herbicide.

There is relatively little resistance to pre-emergent herbicides present in NSW, with some resistance to trifluralin, prosulfocarb and s-metolachlor + prosulfocarb (Boxer Gold) in annual ryegrass. If resistance to these herbicides is known to be present, alternative products should be chosen.

Too little persistence is a problem for products such as s-metolachlor + prosulfocarb (Boxer Gold), prosulfocarb and metazachlor (Tenet®), where the efficacy of the herbicide declines rapidly after application. This allows later emerging weeds to avoid the herbicide. This is also more likely to be a problem in higher rainfall zones or in longer seasons. The solution is to use longer persistence products and mixtures of pre-emergent herbicides.

Loss of herbicide out of the root zone of the germinating weeds mostly occurs with the more soluble herbicides, such as metazachlor (Tenet®) and cinmethylin (Luximax) and generally on lighter soil

types. However, this can be a problem for many herbicides with sufficient rainfall. In higher rainfall regions, using herbicides with lower water solubility will manage this problem.

Too little rainfall after application of the herbicide is normally a problem for the less soluble products, such as pyroxasulfone (Sakura), propyzamide and aclonifen+diflufenican+pyroxasulfone (Mateno® Complete). This typically occurs where there has been good rainfall prior to application of the herbicide that causes annual ryegrass to germinate. Without sufficient follow-up rainfall after herbicide application, the herbicides are not activated in time to control the weeds. Mixtures with herbicides that have different properties can overcome this problem. Useful mixtures have been pyroxasulfone (Sakura) plus tri-allate (Avadex® Xtra) and pyroxasulfone (Sakura) plus trifluralin.

An early post-emergent application of s-metolachlor + prosulfocarb (Boxer Gold), prosulfocarb (Arcade) or aclonifen+diflufenican+pyroxasulfone (Mateno® Complete)can be used in combination with the pre-emergent herbicide to manage the potential issues with pre-emergent herbicides. All of these herbicides require rainfall after application to activate them. S-metolachlor + prosulfocarb (Boxer Gold)is the most water-soluble product, requiring the least amount of rainfall, followed by prosulfocarb (Arcade), whereas aclonifen+diflufenican+pyroxasulfone (Mateno® Complete)is much less water soluble. S-metolachlor + prosulfocarb (Boxer Gold)and prosulfocarb (Arcade) are best applied when annual ryegrass is at the 1 to 2-leaf stage. Aclonifen+diflufenican+pyroxasulfone (Mateno® Complete), because of the higher rainfall requirement, is best applied as a strategic application rather than for salvage and at the 2-leaf stage of the crop, preferably before additional annual ryegrass has emerged. Aclonifen+diflufenican+pyroxasulfone (Mateno® Complete) will control new emergence of annual ryegrass after rainfall has occurred but will not control larger annual ryegrass plants.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

The trial at Gawler was funded by the South Australian Drought Resilience Adoption and Innovation Hub funded by the Department of Agriculture, Fisheries and Forestry through the Future Drought Fund. The trial was conducted in collaboration with Elders.

Contact details

Chris Preston
School of Agriculture, Food & Wine
University of Adelaide
Ph: 0488 404 120
Email: christopher.preston@adelaide.edu.au

Date published

February 2024

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