Reducing glyphosate resistance risk

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Most actions in agriculture carry some kind of risk. Good management is about choosing which risks to take and minimising undesirable risk – and this is as true of weeds and herbicide resistance as it is of any other area of decision-making. Our approach with computer modelling work has been to predict and assess the relative riskiness of different kinds of farming systems and weed control strategies, with respect to the evolution of herbicide resistance.

The model predicts that more than a decade of zero-till farming with no summer cropping and a constant reliance on glyphosate for fallow weed control is highly risky activity for developing glyphosate resistance problems in summer grasses. As shown in Figure 1, a population of barnyard grass could become predominantly resistant within 15–17 years (Grower A).

Mix it up with IWM

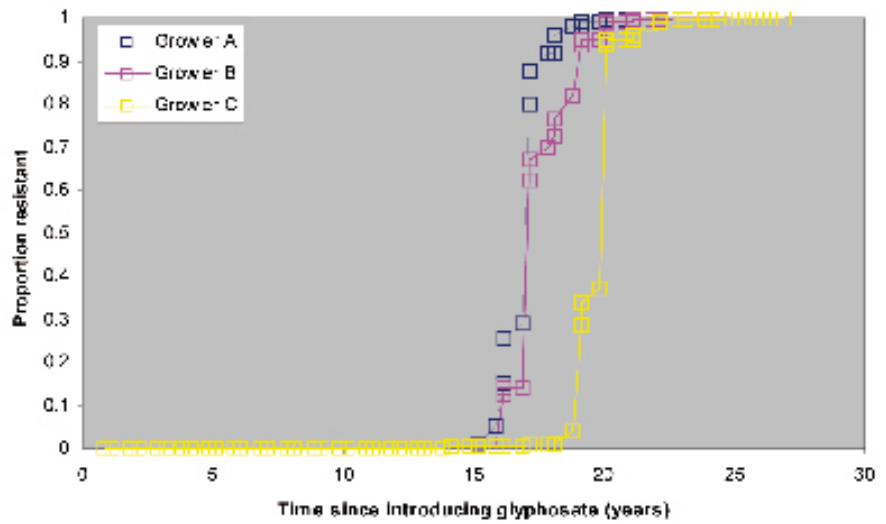
It's important to avoid relying entirely on one single herbicide mode of action. Using a range of integrated weed management strategies (IWM) mixes up the methods of weed control being used in the paddock, targeting weeds at different parts of the weed life cycle. Two key integrated tactics suitable for summer grass control are to rotate herbicide mode of action groups for knockdown grass control, and to rotate between summer and winter cropping, adding a selective herbicide in the cropping phase.

Predictions for different levels of IWM for summer grass control are shown in Figure 1 (Growers B and C). Grower B is similar to the 'high-risk' Grower A, but rotates to a summer crop (sorghum) once every five years. Grower B uses a residual selective herbicide (for example, atrazine or Dual Gold) at planting, but gets only average to good efficacy from this herbicide. As a result, there is a minor reduction in the rate of evolution of glyphosate resistance, and therefore the risk level for this farming system is still high.

Summer cropping is not frequent enough, and efficacy from the residual herbicide not high enough, to make a real difference.

Grower C rotates to sorghum twice in every five years, gets higher efficacy from the residual selective herbicide used pre-planting, and plants at a higher density to ensure greater crop competition. However, no actions are taken to prevent seed set on glyphosate survivors. In this case, resistance is still predicted to occur, but approximately four years are added to the useful lifespan of glyphosate. Therefore we say that this is a moderately risky farming system. A more intensive IWM strategy would be needed to further reduce glyphosate resistance risk.

FIGURE 1: Three simulations of barnyard grass evolving glyphosate resistance



Grower A: Zero-till fallows only, no herbicides other than glyphosate.
Grower B: Zero-till summer fallows excepting one sorghum crop per five years with average efficacy (maximum 80 pet cent kill) from a residual selective herbicide applied at planting.
Grower C: Zero-till summer fallows with glyphosate use, excepting two sorghum crops per five years with highly effective (maximum 95 pet cent kill) residual selective herbicide use pre-planting.

Act sooner, not later

Risk of glyphosate resistance can be reduced by taking action sooner rather than later. We simulated a situation in which a grower switches from solely relying on glyphosate in summer, with no summer cropping, to a program of targeting glyphosate survivors to prevent seed set.

A double knock strategy (glyphosate followed by a second knockdown herbicide with a different mode of action) is used to provide control of survivors of the glyphosate application (including any resistant plants). We varied the number of years before the switch to double knock was made, and the results showed that the longer the wait, the faster the weed population developed glyphosate resistance (Figure 2).

KEY MESSAGES

A week may be a long time in politics, but when it comes to herbicide resistance, it is a farmer's decisions and actions over a course of years that determines the level of risk they're exposing themselves to. Our new computer modelling work has uncovered some key points about herbicide resistance in weeds of the northern region:

- Zero-till or minimum-till farming, relying strongly or entirely on glyphosate, is a high-risk activity for glyphosate resistance.
- Mixing it up, using integrated weed management and cropping diversity, is likely to provide the best answers for long-term prevention of herbicide resistance.
- Acting sooner rather than later is important – more value is obtained from preventative tactics the sooner you start using them.
- Controlling seed set on glyphosate survivors is critical for both prevention of resistance and management of already-resistant weed populations. Strive for 100 per cent weed control whenever possible.

Conversely if seed set control practices are taken up after only seven years, no resistance is apparent in the population even after 30 years. This shows that controlling glyphosate survivors helps reduce the risk of glyphosate resistance, and also that acting now to reduce selection pressure – rather than waiting for signs of resistance in the paddock – is the best policy.

Control seed set on glyphosate survivors

In the double knock scenarios above, we assumed that 95 per cent of glyphosate survivors were killed, preventing them from setting seed. While 95 per cent is a high figure, when a weed species like barnyard grass can produce 10,000 seeds per plant or more, 95 per cent is not high enough to produce clean paddocks or to remove the risk of glyphosate resistance completely. We were interested in the difference between high levels of control, and complete control (100 per cent kill).

Three summer cropping scenarios are shown in Figure 3, two with 100 per cent control of glyphosate survivors in some or all flushes of barnyard grass in the fallow years (Growers D and E). These strategies compare well to the maximum risk scenario (Grower A), by extending the useful lifespan of glyphosate on the weed population by five to six years over summer cropping alone if only the main flush is controlled (Grower D). If all summer fallow germinants are controlled at 100 per cent, we predict that the population will not show measurable levels of resistance even after 30 years (Grower E).

While this very high level of control is difficult to reach in the field, it is clear from these results that it's important to strive for 100 per cent control, preventing seed set on glyphosate survivors, as often as possible. No seed set on resistant glyphosate survivors equals no resistance problem! Under this type of strategy, weed numbers in general are also kept very low.

Risk estimates and impact

It's not easy to look at all this information, and the hundreds of other simulations that have come out of the model, and make choices and predictions directly for a particular paddock. Because of this we decided to distil as much of the information as possible into a risk management tool. We've put this together as a questionnaire that farmers can use to assess the level of glyphosate resistance risk they're facing.

The questionnaire was developed for glyphosate resistance and barnyard grass, and it estimates current risk of resistance given a set of historical practices.

Using the questionnaire is just a matter of answering each of the six questions and adding the scores together. Then compare your total against the categories at the end. If you score in the low or very low ranges, you may not need to make any changes to your farming system. If you score in the high risk range, this is a strong indication that you should make some changes to reduce your risk. Most paddocks with a history of more than 10 years of zero-till summer fallows relying heavily on glyphosate will fall in this high risk range, unless they have been taking frequent preventative actions like rotating herbicides and/or controlling glyphosate survivors frequently.

Reducing risk

The information in the questionnaire can also be used to identify ways of reducing glyphosate resistance risk. In questions 2–6, some answers give a negative score, which can offset some of the risk of a long-term zero-till farming system that relies mainly on glyphosate. A paddock with

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FIGURE 2: Glyphosate resistance evolution rates as affected by timing of two-year intensive double knock programs (all weed flushes in the two years listed are targeted with double knock) followed by annual double knock on the largest flush

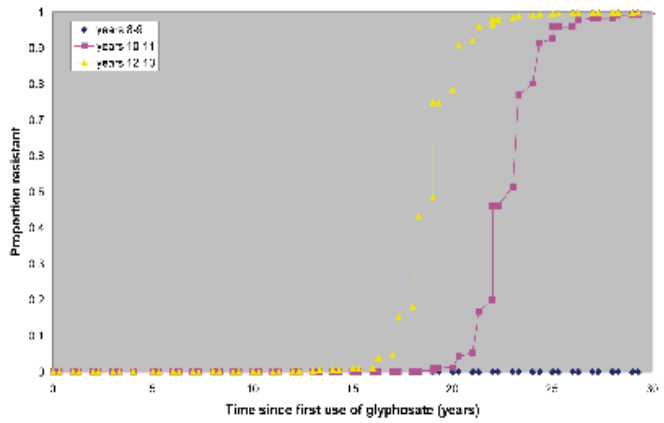
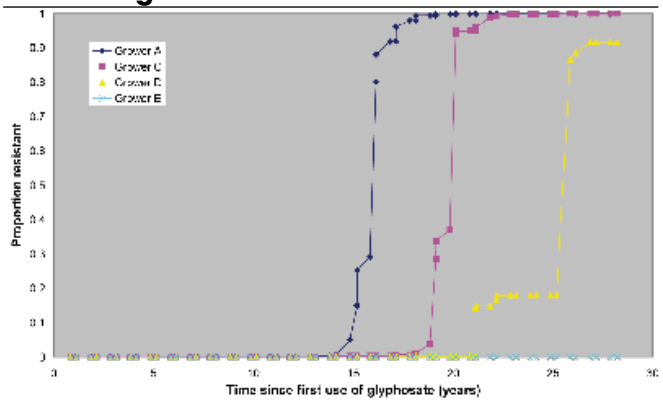


FIGURE 3: Rate of glyphosate resistance evolution in barnyard grass under four weed control regimes



Grower A: no control of glyphosate survivors, no summer cropping.
Grower C: two summer crops every five years, no control of glyphosate survivors.
Grower D: two summer crops every five years and 100 per cent control of glyphosate survivors in some flushes in summer fallows.
Grower E: two summer crops every five years and 100 per cent control of glyphosate survivors in every flush in summer fallows.

◁vii...GLYPHOSATE RESISTANCE RISK

10 years or more of zero-till summer fallows, where no attempts were ever made to control glyphosate survivors and there has been no rotation to alternative herbicides, would score as having a high risk of glyphosate resistance. If the manager of that paddock decides to switch to frequent uses of an alternative herbicide mode of action, and control survivors on most flushes of barnyard grass, the questionnaire shows that risk into the future would decrease.

So the questionnaire encourages the adoption of each of the key strategies for resistance prevention:

- Controlling herbicide survivors to prevent seed set;
- Rotation between summer and winter cropping including the use of selective residual herbicides;
- Rotating knockdown herbicide modes of action; and,
- Using strategic tillage where possible.

GLYPHOSATE RESISTANCE RISK EVALUATION QUESTIONNAIRE

1. How many zero–till summer fallows with reliance on glyphosate have been carried out in this paddock?					
	0	1–5	6–10	11–15	16+
Score:	0	2	6	8	10
If all these fallows have been consecutive, multiply this score by 1.5					
2. How often do you try to prevent glyphosate survivors from setting seed?					
	never/rarely	some flushes	most flushes	every flush	
Score:	5	0	–2	–5	
3. How often do you prevent 99 per cent or more glyphosate survivors from setting seed?					
	never	some flushes	most flushes	every flush	
Score:	0	–1	–3	–5	
4. What is the average number of summer crops with good selective herbicide use per five years in this paddock?					
	0	1–2	3–4	5	
Score:	6	3	–1	–6	
5. How often, on average over five years, is an alternative knockdown used instead of glyphosate in this paddock?					
	0–3	4–8	9+		
Score:	0	–2	–6		
6. How many times, on average over five years, is a large flush of the target weed controlled with tillage in this paddock?					
	0–3	4–8	9+		
Score:	0	–2	–6		
SCORING: Add scores for questions 1–6 together.					
<0 to 0: Very low risk. 1–6: Low risk. 7–12: Medium risk. 12+: high risk					

How does the model work?

The resistance model uses the crop model APSIM to simulate the growth and seed production of wheat, sorghum, and barnyard grass, and competition between them when more than one species is present. Additions to APSIM were made, to simulate mating between resistant and susceptible plants in the weed population, as well as seed bank processes like numbers of seed germinating, mortality, predation, and seed aging.

We included farming system factors such as when and how effectively weed control methods are used, planting and germination dates based on climate data, and what stage of a rotation a particular paddock may currently be in.

Based on the current sizes of the resistant and susceptible populations, the model calculates a current level of resistance. Changes in this value over time track how quickly resistance to glyphosate might be evolving.

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