Three reasons why mix and rotate herbicides is better than just rotate

Peter Newman and Roberto Busi, Australian Herbicide Resistance Initiative

Over the years we have done a great job of communicating the message of herbicide rotation to delay herbicide resistance. 'If you use a herbicide this year, don't use it next year', and so on. We have also talked about the double knock technique, and also how it is important is when mixing herbicides to ensure that both herbicides are at full rates. Now it seems that the ultimate answer is to mix and rotate herbicides. Don't just mix, and don't just rotate – we need to do both. In this paper I will give three pieces of evidence to show why the mix and rotate message is better than simply rotating.

1. **"Rotating buys you time, mixing buys you shots", Pat Tranel**

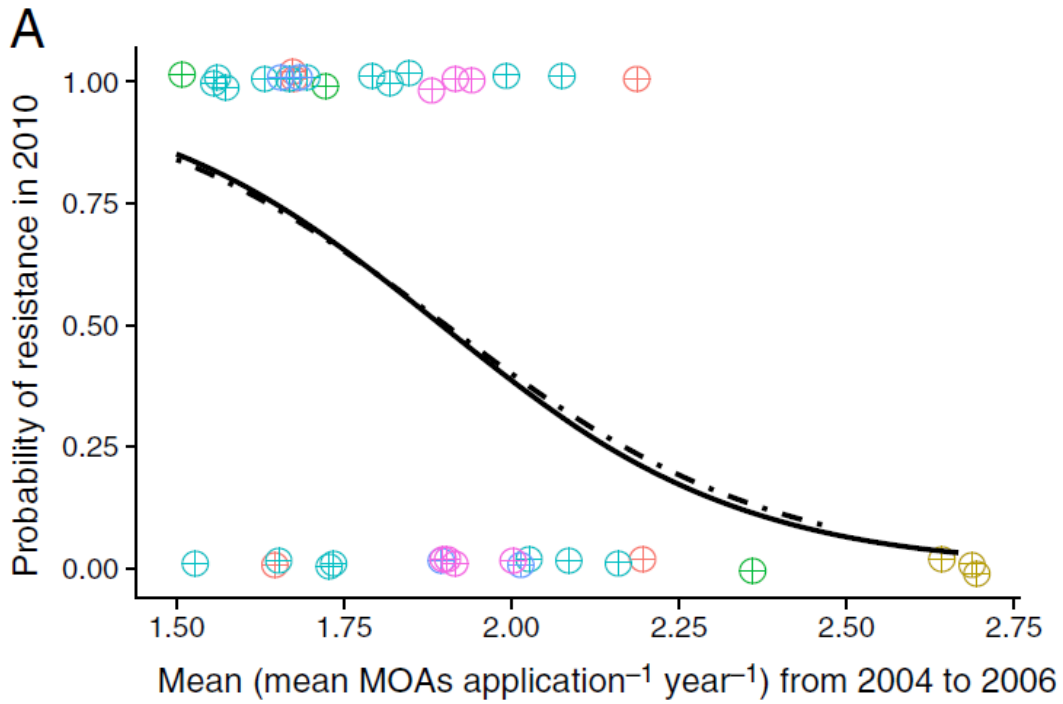
If you have a herbicide where resistance typically evolves after five shots, then using it every second year will buy you some time, but resistance will still happen after five shots over ten years. Mixing this herbicide with other herbicides, all at full rates, is likely to buy some extra shots of the herbicide.

Back in 2006, Pat Tranel and others from the University of Illinois, USA were investigating the first reports of glyphosate resistant waterhemp in the USA. As they travelled around they saw completely weed free fields, while other fields had glyphosate resistant waterhemp exploding out of the top of the crop. Fast forward to 2010 and these same researchers set out to discover why. They worked with a local spray contractor who provided them with nearly 500 site years of data from 105 fields. They found that the difference was due to management, specifically, growers that have used full rates of herbicides in mixes. Growers that used 2.5 herbicide modes of action (MOA's) on average per application were 83 times less likely to have glyphosate resistance than growers that had mixed 1.5 MOA's on average. They concluded that mixing herbicides is better than rotating between them to prevent herbicide resistance.

Prof Pat Tranel is a researcher at the University of Illinois, USA. He and the other researchers in this study looked at a huge range of variables, 61 in fact. They looked at everything from environment, to soil, to landscape and management and found that what mattered most was mixing herbicides.

Mixing is where it's at

The graph below says it all. The researchers reviewed herbicide application from 2004 to 2006 and then did glyphosate resistance tests in 2010. The probability of resistance in these fields declined sharply as more products were added to the tank. (MOA = mode of action = herbicide group).

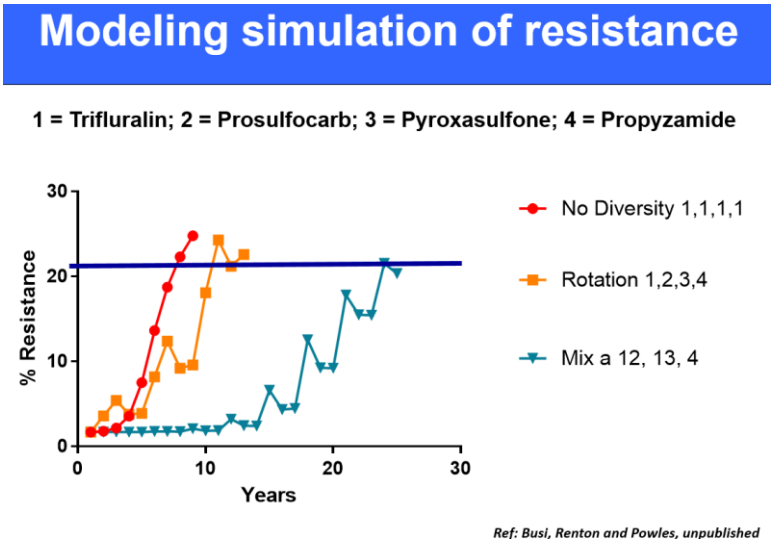


2. Computer modelling

Dr. Roberto Busi from AHRI and Dr. Michael Renton from UWA have undertaken some computer modelling that also shows the benefits of mixing and rotating herbicides. Roberto managed to evolve cross resistance to Sakura® (Pyroxasulfone) and Boxer® (Prosulfocarb) in the lab. This is of great concern as these herbicides are in different herbicide groups. He and Michael used these results to build a computer model. The model assumes the same resistance gene frequency for trifluralin, Boxer, and Sakura, whereas Propyzamide has a lower resistance gene frequency.

This is preliminary data, and only shows a small selection of the results, however it does show what we suspect, mixing and rotating herbicides is the way to go. The graph below shows the probability of resistance evolving to one of the herbicides. We don't know which one is evolving resistance first.

Here is the thing, this modelling shows that sometimes increasing the use of a herbicide can protect it and / or its mixing partners. For example, where trifluralin is used once in every four years in rotation with other herbicides, one of the herbicides fails within about eleven years. Whereas using trifluralin in two out of three years, when mixed with Sakura® or Boxer®, it takes 22 years before one of the herbicides fails.



3. Why does this work? Multiple mutations are rare

Essentially, it's very rare for a single weed to be resistant to two herbicides before herbicide selection. If a weed gains a random mutation that gives resistance to a herbicide, and it is sprayed with two herbicides, at full rates, it will die and not set seed.

BUT

It is important to stress the bit about 'before herbicide selection'. If a weed is resistant to one of the mixing partners then this is not an effective mix. For example, the best time to use the double knock is before glyphosate resistance has occurred in the population. Whereas if glyphosate resistance is already present, and then we start using the double knock of glyphosate followed by paraquat, then paraquat is the only effective herbicide and we are putting excess pressure on paraquat.

What is an effective mix?

We use a lot of herbicide mixes in Australia, but many of them do not include all of the herbicides at full rates. In many cases, crop safety and herbicide labels do not allow us to use all products in the mix at full rates. However, there are plenty of examples where we can use mixes of herbicides at full rates and we owe it to ourselves to do so whenever practical.

A good herbicide mix is;

- Two or more herbicide groups (MoA)
- Each at full rates for the target weed
- There is no resistance to any of the herbicides in the mix
- No antagonism between herbicides
- Physically compatible
- Safe to the crop
- Cost effective

Achilles heel of herbicide mixes

Cross resistance between herbicides due to non-target site resistance is the Achilles heal. Some resistance mechanisms can give cross resistance to a number of herbicides e.g. metabolic resistance through P450 enzymes (this does not apply to glyphosate). This is a threat to the mixing strategy as a single weed may be resistant to multiple herbicides. And even if we do not have cross-resistant weeds, and our rotate and mix strategy works really well, we need to think proactively. Yes resistance to mixtures is rare although resistance to mixes will inevitably occur. This is why it's essential to not rely on herbicides alone.

Summary

This research shows that mixing herbicides is better than simply rotating between herbicides from year to year. We can go one better, and hit the weeds with more knocks that don't come in a drum.

The old rock star adage is 'live hard, die young'. Keith Richards, on the other hand, has somehow managed to buck the trend and 'live hard, (and will) die old'. Many herbicides are 'living hard, dying young'.

We need to work out how to get herbicides to 'live hard, die very old'. Mix and rotate is part of the solution.

Acknowledgements

Roberto Busi and Michael Renton for their research and computer modelling. Pat Tranel from the USA for his research. GRDC for their ongoing support of AHRI.

Peer reviewed by Dr. Roberto Busi