How glyphosate will survive changes in herbicide use

By Dr Charlie Reinhardt

Most commercial crop producers the world over will likely agree that glyphosate deserves to be hailed a once-in-a-century herbicide. In stark contrast, many politicians and activists who lobby against genetically modified crops, specifically crops that are Roundup Ready® or glyphosate resistant (GR), are bent on seeing the demise of two technologies that revolutionised crop and food production in the era of modern agriculture.

An article titled *Are herbicides a once-in-a-century method of weed control?* makes a case for herbicides being an exhaustible resource that can be depleted through use, due to the scourge of herbicide-resistant (HR) weed. The article cautions that a paradigm shift in weed management strategies is required for glyphosate and other important herbicides to remain valuable tools for sustainable, profitable crop production.

The advent of GR crops with Roundup Ready® soya beans in 1996 prolonged and accelerated glyphosate use at a time when Monsanto's patent rights on glyphosate were about to lapse after it came on the market in 1974. Unfortunately, the first GR weed, *Lolium rigidum* (rigid ryegrass), was also reported in Australia in 1996. Since then, the number of GR weed species has increased to 45.

Herbicide-resistant weeds

To put the number of GR weeds into perspective, there are currently a total of 259 weed species for which herbicide resistance has been proven. Herbicide resistance exists in 23 of the existing 26 herbicide sites of action. Some 167 different herbicides are involved in 93 crops in 70 countries.

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As far as herbicide groups based on sites of action are concerned, the group that inhibits the acetolactase synthase (ALS) enzyme leads the pack, with resistance reported in 162 weed species. The groups that inhibit photosynthesis come in a close second with little more than 100 weeds. However, due to the enormous scale of glyphosate use in the United States, the estimated costs of GR weeds in maize, cotton and soya beans have reached $1 billion per year.

Fundamental to the 'wicked' nature of the herbicide resistance phenomenon is the perplexing irony that glyphosate's success and popularity have been the strongest drivers for the selection of resistance in weeds. The domination of glyphosate as a weed control method inevitably reduced not only diversity in herbicide modes of action employed on crop fields, but also in non-chemical control practices such as mechanical weed control.

This scenario is not limited to GR crop systems, but also fits snugly with zero-tillage practices where herbicide use is the only effective option. Against this background, it could seem inconceivable that the dire consequences of over-reliance on, and over-use of, a single weed control measure were overlooked, and for so long.

It could be argued that the sheer brilliance of glyphosate and its spin-off GR crop technology were irresistible in light of benefits such as lowered input costs, broad-spectrum weed control, zero risk to following crops due to negligible persistence in soil, and zero toxicological consequences for the environment.

Table 1: Key commercial genetically modified (transgenic) multiple HR crops. (Source: JM Green, 2018)

Herbicide types	Crops made resistant
Glyphosate + glufosinate	Soya beans, maize, cotton
Glyphosate + glufosinate + 2,4-D	Soya beans, cotton
Glyphosate + glufosinate + dicamba	Soya beans, maize, cotton, wheat
Glyphosate + glufosinate + HPPD-inhibitors	Soya beans, cotton
Glyphosate + glufosinate + 2,4-D + ACC-inhibitors	Maize

An overdue paradigm shift

The seemingly endless struggles of producers and weed control practitioners in relation to HR weeds have recently attracted the attention of economists and sociologists alike. A broader, holistic approach to dealing with this 'wicked' problem is required.

Economists recognise that the efficacy of any pesticide, including herbicide, is an exhaustible resource that can be depleted through use over time in much the same way as the exploitation of minerals, petroleum, water in aquifers, or the management of antibiotic resistance.

No novel herbicide modes of action have been developed for more than 30 years, and the pipeline for new chemistry reaching the market appears to be severely constricted for the foreseeable future. It can take seven to ten years from patent filing to commercialisation, and research and development costs can reach $200 to $300 million per compound.

Patenting issues

This delay in the process halves a typical patent length of 20 years, and hence, the combination of time and cost could be a disincentive for developing novel chemistry. Further limiting the prospects of new chemistry is the reduction in chemical companies trying to develop new herbicides, from 45 in 1970 to four in 2018.

Alternative weed control methods such as cover crops, organic mulches and crop rotation are not patentable. Therefore, the private sector's funding of research and development is limited. In contrast, patentable innovations for mechanical weed control include harvest weed seed control, a method that was invented in Australia, as well as drones and robotics.

Social value is associated with the integration of weed control tactics that are not patentable. Hence, public funding for research in this area is likely to be forthcoming from government research institutions, universities, non-governmental organisations and organised agriculture.

History of herbicide resistance

In dealing with HR weeds on-farm, there is evidence that 'techno-optimism' lulls producers into a false sense of security based on historical assistance provided by herbicide companies through the rapid introduction of new chemistry to deal with HR weeds.

Avoid relying on a single practice, whether chemical, cultural, biological or mechanical. The highest level of precision at all stages of herbicide use will certainly reap the rewards.

When resistance to triazine herbicides, such as atrazine and simazine, surfaced in the 1970s, new chemistry in the form of ALS-inhibiting herbicides, such as chlorsulfuron, became available. However, weeds resistant to ALS-inhibiting herbicides were first recorded in 1978, and resistance to the then latest new chemistry, the ACC-inhibiting herbicides, was recorded in the 1980s.

In the 1990s, when cases of resistance to all the aforementioned and other important modes of action increased at an alarming rate, hope for solutions fell on glyphosate and the brand-new biotechnology of GR crop varieties. Unfortunately, the first case of glyphosate resistance in a weed species was confirmed in 1996.

By the year 2000 it had dawned on all stakeholders that novel chemistry was no longer going to come to the rescue, at least not in the short term. With the realisation that 'old' chemistry would have to be optimised, and in some cases resurrected, the value of combining different modes of action in the same spray tank was recognised and became best practice.

Ready-formulated mixtures and tank mixtures became popular, the latter sometimes to the extent that unregistered mixtures are concocted which either fail to control weeds or injure crops.

Solutions to the problem

Third-generation HR crops that combine glyphosate traits with other herbicide traits (*Table 1*) signalled the end of the 'Roundup Ready revolution'. The preceding second-generation GR crops involved improvements by Monsanto (now Bayer) to first-generation technology.

Table 1 indicates the triple HR crops with resistance to glyphosate and glufosinate plus another herbicide contributing a third mode of action that are the most prominent nowadays. Will such biotechnology eradicate herbicide resistance? Robert Fraley, executive vice-president of Monsanto at the time it was taken over by Bayer, is positive it can be achieved by 2050. However, as can be expected, not everyone fully agrees with this projection.

The surest way to secure the future of herbicides for sustainable, profitable crop production is to incorporate their use into precision agriculture. Integrating herbicides with biological, cultural and mechanical control methods will bring much-needed diversity into weed management strategies.

Avoid relying on a single practice, whether chemical, cultural, biological or mechanical. The highest level of precision at all stages of herbicide use will certainly reap the rewards. Only in such a setting will magnificent 'old' herbicides such as glyphosate continue to render an invaluable service to producers and society.

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