



The implications of herbicide tolerant GM crops

Murray Scholz

Grain grower, Culcairn, NSW & Nuffield Scholar 2008

IN A NUTSHELL

- Canada has been successful in using the herbicide tolerant genetically modified crop technology, achieving higher profits and cleaner paddocks.
- The USA has also had success but the lack of crop rotation, and the continuous growing of herbicide tolerant genetically modified crops is leading to major issues with glyphosate resistant weeds especially in cotton.
- Australian farmers will benefit from access to herbicide tolerant genetically modified canola varieties, which should provide better weed control and yields than the triazine tolerant varieties – but there needs to be a diverse rotation that has a two year gap between herbicide tolerant genetically modified crops.
- In conjunction with the new technology, farmers also need to use integrated weed management techniques like pre-emergent herbicides, diverse rotations, rotation of knockdown herbicides and non herbicide methods.

This article is adapted from a Nuffield Scholarship report

For twelve years, as Australia debated the merits of genetically modified crops, many other countries especially Canada and USA enthusiastically adopted the technology. In 2008 approval was given for Australian farmers to grow genetically modified, herbicide tolerant canola.

Farmers, agronomists and regulators in Australia need to know that while this technology has many advantages; if it is abused through poor management the price is high. If weeds develop resistance to the herbicide glyphosate it will limit farmers' management decisions and add complexity and cost to winter cropping systems. The timeline for new herbicides to replace glyphosate are an unknown. It is possible that there will be no new herbicide modes of action developed.

The comments and opinions expressed in this paper are my own and are based on my personal findings. No responsibility can be attributed to Nuffield Australia or any affiliated party.

Learning from experience

In 2008, NSW and Victoria lifted their moratorium on growing genetically modified, herbicide tolerant canola. Australian farmers now have another tool for the management of weeds and to help them deal with the herbicide resistant weeds they already have. Proponents of the technology assert that this will be a major step forward but opponents claim that farmers will end up with bigger herbicide resistance problems.

This study was undertaken to see what twelve years of growing herbicide tolerant genetically modified (HTGM) crops in North America has meant for weed management. I wanted to see what changes had occurred and see what mistakes have been made so that we in Australia don't repeat them. I also visited

Europe looking at weed management without herbicide tolerant genetically modified crops. I wanted to see how farmers are dealing with fewer herbicide options and if organic arable farming has some techniques that are applicable to southern Australian winter cropping systems.

The aim of this study was not to discuss the merits of genetically modified crops. Many others have done that before this report. I will make a few comments, but the goal of my scholarship was to provide information to Australian farmers so that they can responsibly and sustainably use herbicide tolerant genetically modified crops.

The Canadian experience

Over 95% of canola grown in western Canada is herbicide tolerant to glyphosate, glufosinate or imidazolinone. It gives Canadian growers effective weed control and higher profits. Take-up was rapid and within five years of introduction over 80% of canola grown was HTGM. Growers like the technology because of easier management and better control of weeds like mustard (*Sinapis arvensis*), stinkweed (*Thlaspi arvense*), cleavers (*Galium aparine*) and stork's bill (*Erodium cicutarium*). All of these had been difficult and expensive to control in conventional canola.

Most growers use canola as part of a rotation with wheat, barley and sometimes peas. The standard recommendation from agronomists is to grow canola only once every four years. Some growers have been growing it more often but are running into issues with disease and insect pests.

Canada is a good example of how growing HTGM crops has encouraged the uptake of no-till. Timeliness is important because of a short growing season, the combination of no-till and HTGM crops have allowed farmers to plant earlier. They



now no longer need to wait for weeds to germinate before planting. Farmers can plant, confident they have good control of weeds in crop.

Weeds developing resistance to glyphosate has not been an issue yet. Most Canadian farmers practice good integrated weed management even though the tactics they are using often aren't specifically aimed at weed control. Farmers are using vigorous varieties and high seeding rates in both canola and cereals. Recommended rates for canola are 5–6 kg/ha and for cereals 120 kg/ha. Nearly all of the canola varieties grown are hybrids. Growers like them because of their vigour and yields up to 30% higher than open pollinated varieties.

A lot has been said by some critics of genetic modification about the amount of hybrids grown in Canada and the fact that you can't keep seed from them. The facts are growers have a choice and they are choosing hybrids because they get better weed control because of the better seedling vigour and the higher yields put more money in their pockets. In 2008 there were eight seed companies offering a total of thirty varieties of Roundup Ready canola so growers do have choice.

Liberty Link canola (which is tolerant of the broad-spectrum glufosinate herbicide Liberty®) is also popular with farmers with it planted on 40% of canola acres in 2006. They have good varieties and growers like to rotate the technologies because some are concerned that they may be using too much glyphosate.

Farmers are making higher profits from HTGM canola. Agriculture and Agri-Food Canada (a federal government department) conducted a three year trial beginning in 2001 looking at profitability and how effective weed management was with different herbicide regimes (Table 1).

The trial was conducted in three locations. As you can see the non-glyphosate treatments had more weeds and returned less dollars a hectare. It is not surprising that farmers have embraced HTGM canola.

Eastern Canada uses HTGM soybeans and corn. Around 65% of soybeans are HTGM and 40% of corn. They are usually grown in a rotation that includes winter wheat. Few growers practice no-till because low soil moisture is rarely an issue. Just as in western Canada growers like the technology because of better weed management and higher profits. They too have not had issues with weeds developing resistance to glyphosate. The fact that growers have at least three crops in the rotation, they rotate herbicides and they are still cultivating, is keeping them from problems.

The USA experience

The United States of America grew 54.6 million ha of genetically modified crops in 2006. Not all of those crops were herbicide resistant but the vast majority were. The big three crops of soybeans, corn and cotton make up a very high proportion of the total area.

Many farmers in the mid west states of the US grow a continuous rotation of just corn and soybeans. This is usually corn–soy–corn–soy but in recent years some growers are extending the rotation to soy–corn–corn because of the record prices of corn. There is a mix of tillage systems with the wetter states like Iowa and Illinois tending towards cultivation while drier areas like eastern Kansas and Nebraska tend to no-till systems.



Figure 1. Murray Scholz, a grain grower from Culcairn NSW, believes herbicide tolerant crops can be a valuable tool in an integrated weed management system.

Roundup Ready soybeans

Growers in the US took up Roundup Ready (RR) soybeans (tolerant to glyphosate) very quickly. Weed control in soybeans had been difficult with the only options either a group B herbicide or a group G. Growers didn't like the group G herbicide because it can damage the crop and so were using group Bs on approximately 80% of the crop. Water hemp (*Amaranthus rudis*) is a native North American plant that was regarded as a minor weed before it developed resistance to the group Bs. Before RR soybeans, weed control in soybeans was not satisfactory and growers were resorting to hand chipping of weeds. When RR soybeans became available growers took it up because weed control was good and management seemed easy.

Farmers in the US seem to have a love/hate relationship with companies like Monsanto. They love the RR technology but don't particularly like paying the higher seed costs. One of the consequences has been a reduction in seeding rates by

Table 1. Effect of 'in crop' herbicide treatments on weed biomass and net returns in canola

Herbicide	Weed biomass (kg/ha)	Net return (\$/ha)
Glyphosate x 1	296	\$354
Glyphosate x 2	136	\$321
Ethalfuralin (E)*	1393	\$286
Sethoxydim (S) + Ethametsulfuron (Eth)	1182	\$245
E + S + Eth + Clopyralid	410	\$165

*Ethalfuralin was applied to the soil surface in the fall.
Source: O'Donovan et al. (2006)



Table 2. Survey results comparing cultivation (Bt) and no-till (BtRR) systems in Georgia, USA

Technology	Tillage	Yield (lbs/acre)	Revenue @ 0.65 \$/lb (\$/acre)	Variable costs	Returns above variable costs (\$/acre)
Bt	conv	656	426.4	202.63	223.77
BtRR	strip	1185	770.25	224	546.25

20–30%. The yield of soybeans is not affected by seeding rate but a lower rate means that the crop is less competitive against weeds.

Approximately 5% of the market is conventional varieties for human consumption. As in Canada, they are receiving a premium and segregation isn't an issue. Even with the higher seed costs growers admit they are making higher profits growing GM and don't want to go back to conventional varieties.

Roundup Ready corn

Roundup Ready corn was introduced in 1998 but the take-up was slow. The early varieties didn't perform as well as conventional varieties and growers had plenty of effective herbicide options. As late as 2005 RR corn was only 20% of the market. That changed when Monsanto introduced the Bt gene for control of rootworm. Rootworm had been a big problem in places like Iowa and they were difficult to control. The only way growers could get seed with the new Bt gene was Roundup Ready. Now that they were paying for the RR technology whether they used it or not most decided to use glyphosate for their weed control. By using RR corn it also took away issues with drift from the RR soybeans.

This has led to a situation where a grower can just use glyphosate for weed control because they are growing a RR crop every year. The US growers don't seem to like the Liberty Link system and so there is no rotation of herbicides.

"Roundup Ready technology made ordinary farmers into good farmers.....but only for a while"

Phil Stahlman Weed scientist Kansas State University

A Roundup Ready system

Going to a total RR system in the corn–soybean rotation has, I believe, made farmers lazy with many just using glyphosate for weed control. When they started growing RR crops it was easy to just go out with glyphosate and the weed kill and profits were good. Many are trying to cut costs by cutting rates or delaying the 'in crop' application of glyphosate as late as they can so that they only need one application. This is putting a lot of pressure on the herbicide to kill some very large weeds, some that have a natural tolerance to glyphosate. I feel that this is also false economy as what they save in herbicide they have lost in nutrient removal by the weeds. Where cultivation is the norm, because it is a form of non herbicide weed control they are currently staying on top of glyphosate resistant weeds.

The better farmers are still using pre-emergent herbicides and are very aware about applying glyphosate in ideal application conditions and not cutting herbicide rates. Weeds scientists I spoke to believe that glyphosate resistance will explode in the next five years in the corn–soy rotation. With current practices, farmers are removing susceptible weed populations by using glyphosate several times every year.

Roundup Ready cotton

Roundup Ready cotton was introduced to the US market in 1997 and was taken up quite rapidly to where it is currently 85% of the area grown. Before RR cotton, growers' typical weed management involved a pre-plant tillage, 3-5 herbicides applied at least three times during the cropping season and two 'in crop' cultivations between the rows. When they went to RR this changed to one application of glyphosate before planting, and then four applications of glyphosate in crop. A survey of fields in Georgia in 1999 shows why no-till RR cotton became so popular (Table 2).

When it comes to weeds, cotton is a poor competitor and needs eight weeks of weed free growth following planting to make maximum yields. One of the biggest problem weeds for the southern states is Palmer amaranth (*Amaranthus palmeri*). Before the advent of RR cotton, growers had Palmer amaranth already resistant to group Bs and atrazine. Up to 10 years of continuous cotton with the only weed control being up to five applications of glyphosate a year has, not surprisingly, led to problems. It is believed in the state of Georgia that there is somewhere between 100,000 and one million ha of cotton country with some level of glyphosate resistant Palmer amaranth. In the next couple of years this is expected to rise to 30% of the total cotton area. Even though they are having problems, growers are still using glyphosate on fields with resistant weeds because they are paying the tech fee.

This situation is as close as agriculture has come to the feared "super weed" that opponents of GM technology rail about. It is probable that somewhere in the US a field has Palmer amaranth that is resistant to group Bs, atrazine and glyphosate. This has NOT occurred from gene shift but from very bad management on the part of the US cotton industry.

It is expected that new HTGM technologies won't be available till 2014 so major changes will have to be made in how cotton is grown. Growers are going to have to return to tillage, cover crops and rotations with other crops. One could easily argue that they should have been doing that all along. It is expected that growers will spend an extra \$400 million a year in extra herbicide trying to deal with the situation they are in.

The reasons for HTGM failure in the US

Why is it that a technology that is so successful in Canada has developed or is developing so many issues for its neighbour, the USA?

Opponents of GM are quick to say the technology is inherently flawed and doomed to failure but if that was the case Canada would be having just as many problems. At the end of the day the technology has not failed. What has failed has been the management of the technology and just plain out bad farming practices.



Figure 2. Glyphosate resistant Palmer amaranth in cotton Hoke County North Carolina. Photo courtesy Cotton Incorporated.

The lack of rotation of herbicide groups and crops together with a general lack of non herbicide methods has come together in creating a glyphosate resistant weed problem. The bad farmers reaped the rewards for awhile but now there is a price to pay.

"Tell the farmers of Australia to rotate their crops and their herbicides"

Herb Mattson, Farmer Colby Kansas

Growing HTGM crops doesn't automatically give you glyphosate resistant weeds. What management strategies growers adopt will determine if and when they get resistance. The US cotton industry is a good example. They have now made the same mistakes three times, first with atrazine then group Bs and now glyphosate.

Part of the reason of the poor management of HTGM crops in the USA lies at the feet of the Farm Bill and its programs. Corn, soybeans and cotton are three of five crops that receive the bulk of the government assistance. The US national research council looked at the effect of farm programs and it found that they have an enormous influence on the way farmers manage their farms. It also found that the commodity programs promoted specialisation in one or two crops and penalised those farmers who adopted rotations. It felt that farmers often are more responsive to subtle economic effects from the programs than the biological and physical constraints on their farms. I contend that some (not all) of the farmers in the US are farming the government programs and therefore making bad agronomic decisions that are creating issues like glyphosate resistant weeds.

Criticism also needs to be levelled at Monsanto. Insisting that the Bt gene for rootworm in corn be only available with Roundup Ready was, I feel, a short sighted decision that in the longer term will compromise the technology. I realise that developing GM technologies is a very expensive process and companies need to recoup their expenses and make a profit. When Monsanto insist on putting all their technologies in the one plant they are shortening the life of all the technologies and in the long run cutting their profits. As Monsanto is no longer conducting research into new herbicides where do they go as a company if and when most of the soybean, corn and cotton acreage in the United States is covered in glyphosate resistant weeds?

Despite the fact that glyphosate resistance has happened, at this point of time it is on a relatively small percentage of the area planted to HTGM crops. The better farmers who are not relying on glyphosate to do all the work of killing weeds are not having issues. They are using other herbicides as well as cultivation and crop rotation to manage their weeds. Even so there is a strong possibility that the area with glyphosate resistant weeds could increase both dramatically and quite quickly.

The mistakes of the USA are the lessons for Australia. Herbicide tolerant genetically modified crops need to be part of a much wider integrated weed management system and not replace it.

Other pressures on glyphosate

Herbicide tolerant genetically modified crops aren't the only cropping systems that are placing pressure on glyphosate and having weeds resistant to glyphosate. Australia has the dubious distinction of being the first country in the world to develop resistance to glyphosate in a cropping system. This occurred on the Liverpool Plains in northern NSW with ryegrass and barnyard grass.

A number of factors led to resistance developing. The region receives 60% of its annual rain in the summer so growers can grow either summer or winter crops. They are almost exclusively no-till and relied on glyphosate to control weeds in their fallow period. They didn't use residual soil herbicides because they want to be able to opportunity crop and not be limited by residues.

Barnyard grass is a fast growing grass that can set seed in three weeks from emergence. This has often forced growers to apply glyphosate when conditions are less than ideal. Dust and heat can often reduce the effectiveness of the glyphosate applied. Again we see the dependence on just one herbicide leading to problems.

Australia is not alone in using lots of glyphosate for weed control in no till fallows. Low rainfall in the high plains of western Kansas and eastern Colorado means that farmers often only grow two crops in three years. They are also no-till farmers and they use fallows to store up moisture. Up to five applications of glyphosate can be used and it is often at the same timing as if it had been in crop with a HTGM. Problems have not yet developed but there are concerns with weeds like Kochia, which are very close to developing resistance.

Local governments and landowners like railways are also not very creative when it comes to weed management. Many tend to use glyphosate continuously without rotating herbicide groups or considering non herbicide options.

HTGM canola for southern Australia?

The first question that should be answered is whether growing HTGM canola is something that Australian farmers should be doing.

If we look to the Canadian experience the answer in my opinion is yes. I believe that growers will get better yields from RR canola than they do from the triazine tolerant (TT) varieties that most grow now. I also believe that weed control will be better and profits higher even with increased seed cost and technology fees. The big advantage as I see it will be in years when we have late and difficult starts. Farmers will be able to plant their canola dry confident that they will be able to get good weed control in crop. Monsanto and the regulators are to be commended for



Figure 3. A long term trial (running for 12 years) by Kansas State University looking at weed shift with Roundup Ready crops. Left is a plot receiving a full rate of glyphosate. These plots are the cleanest for weeds especially in the more competitive corn. Dr Phil Stahlman who heads the trials believes that resistant weeds are only two or three years away. Right is a half rate of glyphosate plot showing lots of Palmer amaranth. It was interesting to note that after six years yield had dropped dramatically because of weed competition.

putting into place a code of conduct. This should remain in place as it has with the Australian cotton industry. Currently canola growers need to be accredited by completing a course that looks at issues such as paddock selection and crop management, co-existence, herbicide resistance management, and segregation management. I feel that this stewardship program needs to remain in place indefinitely with growers being reaccredited every five years.

Australian growers will need to be proactive in the management of HTGM crops and especially RR canola. Following are some recommendations that I feel are needed to try and prevent weeds developing resistance to glyphosate.


- Use a pre-emergent herbicide and not totally rely on glyphosate.
- Grow hybrid varieties with good seedling vigour to give weeds strong competition.
- Spray when conditions are good and when weeds aren't stressed.
- Budget to apply glyphosate twice in crop. It is better to kill the weeds when they are small and come back with a second application if needed
- Grow canola once every 3–4 years on an individual paddock. The more diverse the rotation and the less 'in crop' applications of glyphosate should extend its life.
- Monitor paddocks after application and be prepared to use another herbicide if results are not up to scratch.
- Use non herbicide methods of weed control like increased seeding rates in the following cereals or burning everything that passes through the header either with a chaff cart or in the row.
- Don't expect it to solve herbicide resistance problems in one year. If the weed seed bank is high one year of HTGM crops won't reduce it to zero. Look at making silage or brown manuring a problem paddock the year before RR canola
- Consider occasional cultivation.

Australian farmers will need to overcome the urge to sit back and relax about weed management because they have HTGM technology. If they use it as part of a wider integrated weed management strategy there is potential to drive down weed

numbers to very low levels. The smaller the number of weeds means a lower chance of resistance developing.

Australia has benefited from the uptake in no-till farming systems. Soil erosion has been reduced, soil carbon levels increased and crops are using water more efficiently. A report recently released by the Australian Farm Institute looked at the value of environmental services provided by Australian farmers. It concluded that reduced tillage techniques in northern NSW between the 1970s and 2002 had an environmental value of \$1.2 billion. The introduction of glyphosate has enabled farmers to adapt to their environment and farm in a way that suits the Australian climate. If there were widespread glyphosate resistant weeds it would limit farmer's ability to continue to no-till.

At the end of the day it is in everyone's interests that we make glyphosate last as long as we can. It has cost herbicide and seed companies lots of money to develop this technology and understandably they want to see profits as quickly as they can. I argue it is also in their interest to make the technology last and to encourage farmers to maintain a diverse rotation that has at least a two year gap between HTGM crops. As we have seen in the past, growers in Australia have pushed rotations with the consequence of weeds developing resistance quite quickly. With the long drought that we have endured farmers need all the profits they can get and will be tempted to push the rotation. Glyphosate is too important to the Australian farming system to let that happen. The last thing Australia needs is to return to the days of multiple cultivations and all the issue that went with that. The timeline for a glyphosate alternative is an unknown. We have to assume that there may not be another mode of action developed and that we need to care for the ones we have.

We as an industry need to decide how we use HTGM technology. The results, success or failure, depend on the decisions we make. 

Further information

Murray Scholz
T: 02 6036 5220
E: mbscholz@bigpond.com

The full version of Murray's Nuffield Scholarship report can be found on the Nuffield website – www.nuffieldinternational.org/rep_pdf/1226027455Murray_Scholz_2008_report.pdf or go to www.nuffield.com.au and follow the links to reports.