Resistance is growing

GM herbicide tolerant crops and resistance to herbicides

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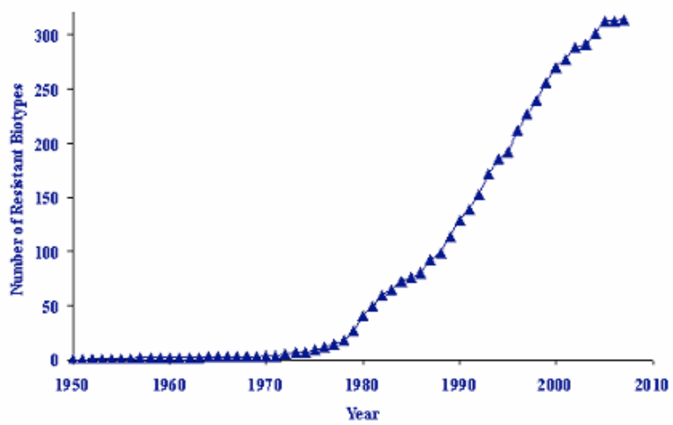
This briefing summarises an examination of the development of GM herbicide tolerant (GMHT) crops and how early predictions that weeds would become resistant to the herbicides used with them have turned out to be correct. It examines the implications of the herbicide "arms race" and the alternatives that exist for managing weeds in arable fields. The full document is available at www.gmfreeze.org.

Background

The numbers of weed biotypes resistant to herbicides has rocketed in the last three decades. Figure 1 shows the rapid escalation in herbicide resistance since the 1980s.

Figure 1: World wide chronological increase in the number of herbicide resistant weeds.



[Source: Heap, I. M. 2007[i]]

At present resistant biotypes exist for herbicides with 16 different modes of action. There are 341 herbicide resistant biotypes of 194 weed species that have been confirmed in over 300,000 fields around the world[ii]. Every continent has herbicide resistant weeds.

Herbicide resistance (to produce resistant biotypes in weeds species) can happen in two ways:

- Through over-use of the herbicide, leading to the natural selection of weed plants (biotypes) which have evolved resistance.
- Gene transfer of herbicide tolerant genes from HT crops to weedy relatives of the crop.

The most common route is by natural selection. The regular use of particular herbicides leads to the selection of resistant individual plants that can then multiply, become more numerous and eventually become dominant if the same chemical is used long enough. One biotype of Rigid Ryegrass in Australia has developed resistance to seven different types of herbicides since1982[iii].

Seed spilled during harvesting can produce HT volunteer plants in following crops of a different species, for example oilseed rape volunteers in cereal crops.

Herbicide Tolerant crops

Crop varieties tolerant to nine different herbicides groups have been bred using conventional techniques and genetic modification. GM Roundup Ready crops developed by Monsanto dominate the market for herbicide tolerant (HT) crops in soya, maize, and cotton. Roundup (active ingredient glyphosate) was thought to be a miracle herbicide that would prevent the development of resistant weeds because of its unique way of killing the whole plant[iv]. One of the main drivers for the development of RR crops was the fact that Monsanto's patent on the glyphosate molecule ended in 2000. They stood to lose market share to generic manufacturers who can produce the chemical more cheaply. By contracting farmers who buy RR seeds from them to also buy Roundup rather than glyphosate-based products made by other companies, Monsanto have succeeded in protecting their market and, indeed, expanding it. Roundup is very important to Monsanto's sales and was responsible for 48% of the total corporate sales in the first quarter of 2008[v].

Herbicide resistant weeds

Farmers have been persuaded to use RR seeds with Roundup because of promise of cheaper and easier weed control and higher yields. However, this has turned out to be a false dawn for farmers. There are now 16 weed biotypes around the world resistant to (glyphosate).

US weed scientists have suggested that the rapid spread of glyphosate resistance in Horseweed in the USA (where 2 million acres are infested) can be traced to the use of no tillage in RR crops:

> "*No-tillage corn (Zea mays L.) and soybean [Glycine max (L.) Merr.] production has been widely accepted in the mid-Atlantic region, favoring establishment of horseweed [Conyza canadensis (L.) Cronq.]. Within 3 years of using only glyphosate for weed control in continuous glyphosate-resistant soybeans, glyphosate failed to control horseweed in some fields. Seedlings originating from seed of one population collected in Delaware were grown in the greenhouse and exhibited 8- to 13-fold glyphosate resistance compared with a susceptible population[vi].*"

Johsongrass, another major arable weed in North and South America, has also developed resistance to glyphosate. It is causing significant farming problems in Argentina where mixes of Roundup and other herbicides, such as MSMA, 2,4D, cletodim or haloxifop and post-emergence graminicides (eg, Micosulfuron, Imazethapir) or for use in fallow fields (atrazine, paraquat, 2,4D and metsulfuron metil). By 2007, glyphosate resistant Johnsongrass covered 10,000 hectares in Northern Argentina, and throughout the country the area may be as high as 100,000 hectares[vii]. A tank mix involving 2,4D and glyphosate has been reported to increase production costs for soya by 19.3%[viii] per hectare and other experts predict a doubling in weed control costs.

A third resistant weed, Palmer Amaranth, has also developed glyphosate resistance over very wide areas in the USA where RR soya, maize and cotton are grown. The problem has reached the point that one weed scientist has said, "*If it ever germinates, we have no products that we can come over the top of, small cotton particularly, and take out glyphosate resistant Palmer Armaranth[ix]".* Twenty-one other weeds in Argentina have been listed as "just barely controlled by glyphosate" and "might be the next to upgrade to full resistance by another evolutionary step".[x]

Thirteen weed species resistant to glyphosate have also developed resistance to one or two other herbicide types (known as multiple resistance). This could make the choices open to farmers even more limited in the future.

Strategies to avoid resistance developing

There are clear steps farmers can take to slow (but not prevent) the development of herbicide resistance in weed population in arable fields where herbicides are routinely used. These are well documented[xi, xii] and many are used in agroecological farming systems where no herbicide use is advocated:

- Vigilance and quick control of resistant populations.
- Crop rotation and avoidance of monoculture developsdifferent weed populations and densities thus preventing the establishment of a resistant population.
- Crop breaks – fallow or temporary grazing systems.
- Hand or mechanical weeding.
- Cultivating soil to kill weed seedlings.
- Mulching using cover crop or weed residues to reduce weed populations.
- Rotations of herbicides with different modes of action.
- Using mixture of herbicides in one spay ("tank mixes").
- Using herbicides that do not persist.
- Combining control methods.

All these measures work towards reducing the selection pressure on individual resistant plants to prevent their biotype becoming dominant in the population. In the case of non-chemical interventions used in agroecological systems, the issue of resistances does not arise because the selection pressure for resistance to develop is removed.

The weed control and monoculture systems adopted for GMHT crops ignore these good agricultural principles and practices despite the fact that "*farmers who practice continuous cropping, or intensive cropping, run a much greater risk of developing resistance.*"[xiii]
The introduction of GMHT crops has meant that many farmers adopted continuous, intensive cropping relying on one herbicide with a single mode of action. This is exactly what they should **not** be doing if they wish to avoid resistance developing.

The agri-biotech approach to weed resistance

Faced with mounting weed resistance to herbicides the agri-biotech industry has responded in two ways:

- By producing GM varieties tolerant to more than one herbicide so herbicides can be rotated to avoid resistance developing.
- By using soil acting residual herbicides to kill off the seedlings of resistant biotypes.

Both approaches increase dependency on chemicals for weed control and hence the toxic burden on the environment. The main weakness in these approaches is that there is an overlap between the products used in each approach, so resistance developed to any product would preclude its use in the other approach.

In addition, many resistant biotypes already have resistances to several herbicides used on HT crops or as soil residuals, so options for a chemical-led approach are already limited by past evolution and mistakes. At best these approaches will delay resistance developing. They are heavily dependent on all farmers co-operating fully which, based on previous reactions to resistance problems, is unlikely to happen. GM Freeze has assessed resistant weeds in US soya and maize crops where GMHT cropping has been most practiced in the last 13 years and found that weed resistance is already well advanced including the development of multiple resistant strains of weeds. Although resistant weeds may be separated by large distances, the incidence of local multi-resistance weed problems is growing. In soya crops, two strains of Common Waterhemp (*Amaranthus rudis)* already have resistance to three types of herbicide, including glyphosate. There are twelve other strains with resistance to two types of herbicide. Of the14 weed biotypes with multiple resistance in soya crops, half are already resistant to glyphosate. There are already seven strains of weeds in maize crops with multiple resistance which includes glyphosate in three cases. Thus there is growing evidence that the weeds are "getting on top" in the "pesticides arms race" in soya and maize in the USA.

Conclusions

Herbicide resistance is a global problem and is accelerating – brought about by over-reliance on chemical weed control and poor management. The development of GMHT crops resulted in good weed control in the early years after their introduction in 1996, but the farming techniques employed by farmers (monocultures, zero tillage and total dependence on Roundup for weed control) have provided an ideal breeding ground for resistance to develop and it has.

The promises of the agri-biotech companies that GMHT would mean simpler weed control and cost savings look very difficult to justify as resistant weeds and volunteers are developing quickly under GMHT crop management. The "solution" from industry is to use different herbicides and stacked herbicide tolerant genes in crops. This will increase the toxic burden on the environment and requires new chemicals to be developed regularly. Indeed without additional chemical herbicides being developed, farmers may have to adopt quite different approaches to weed control, including crop rotation, crop breaks and mechanical weed control.

The problem facing farmers is neatly summed up:

> *"The problem with this attitude is that no new herbicides with novel mechanisms of action are in the latter stages of development, and no herbicides with new modes of action have been released since 1990. Because development time of a new pesticide is at least 11 years and the cost is greater than $190 million, it is unlikely that herbicides with new modes of action will become available to farmers in the next 5 years or longer*[xiv]*."*

The GMHT model of farming has proven to be another phase of the "pesticides arms race" that began in the 1950s when the first weeds resistant to 2,4D were discovered. The model does not fit into the agroecological vision of multifunctional farming set out in the report of the *International Assessment of Agricultural Knowledge, Science and Technology for Development*[xv], which saw no long-term future for farming systems reliant on artificial inputs fuelled by fossil-fuels. Governments around the world need to recognise that the "pesticide arms race", like other arms races, is not, ultimately, winnable, and they therefore need to invest in research and development of alternative weed control techniques based on sound agroecological principles of crop rotation, crops breaks, weed suppression and mechanical weed control. The key to preventing resistance is to have a diverse range of weed control approached rather than depending on one herbicide.

In the absence of a lead by governments and scientists in this transition, farmers need to act themselves, including the re-introduction of previously used weed control methods that have been abandoned since the advent of the GMHT model. Otherwise they risk being overwhelmed by weed resistance problems in the next 20 to 30 years.

Notes

[i] Heap, I, 2007. See www.weedscience.org/In.asp
[ii] See www.weedscience.org/In.asp
[iii] See www.weedscience.org/Case/Case.asp?ResistID=389
[iv] See www.asgrowanddekalb.com/web/products/corn/traits/roundup_ready_corn_2.jsp
[v] See www.reuters.com/article/pressRelease/idUS106176+03-Jan-2008+PRN20080103
[vi] VanGessel, MJ. "Glyphosate-resistant horseweed from Delaware"**.** *Weed Science.* (2001) **49**: pp703-705.
[vii] Ibid
[viii] ibid
[ix] See video clip at http://aaes.uark.edu/nerec_video.html
[x] Valverde B and Gressel J. *Dealing with Evolution and Spread of Sorghum halepense glyphosate resistances and spread in Argentina. A Consultancy report to SENASA.* (2006) See www.weedscience.org/paper/Johnsongrass%20Glyphosate%20Report.pdf
[xi] Mississippi State University Extension Service, undated. *Herbicide Resistance: prevention and Detention.*
[xii] Gunsolus, JL. *Herbicide Resistant Weeds.* University of Minnesota Extension Service, 2008. See www.extension.umn.edu/distribution/cropsystems/DC6077.html
[xiii] *Chaudhry, O. "Herbicide Resistance and Weed-Resistance Management". 2008. See* www.weedscience.org/paper/Book_Chapter_I.pdf
[xiv] See www.weedscience.org/Case/Case.asp?ResistID=5344
[xv] See www.agassessment.org/index.cfm?Page=IAASTD%20Reports&ItemID=2713