



# **Genetically Engineered Backslide: The Impact of Glyphosate-Resistant Palmer Pigweed on Agriculture in the United States**

**by Edward Hammond**

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The Impact of Glyphosate-Resistant  
Palmer Pigweed on Agriculture in the  
United States**

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# Chapter 1

## Introduction

Weeds that resist the herbicide glyphosate are adversely affecting genetically engineered (GE) “Roundup Ready” crops on a large scale in the United States (US). For tens of thousands of American farmers, 2010 will be the year that they revert to 1980s agricultural practices in order to control the rapidly spreading problem. While GE crops have stumbled in the past, the spread of glyphosate-resistant weeds is causing problems more severe and widespread than any GE crop failure recorded to date. It is negating the supposed benefits of GE herbicide-tolerant crops, engineered to withstand applications of herbicide so that only weeds are killed, and shows why it is a deadend strategy for farmers and the environment.

Because of rapidly spreading herbicide resistance, US farmers in large sections of the country now have little choice but to use more chemicals, and more powerful chemicals, on their crops. They are also tilling the land more, resulting in loss of valuable topsoil and release of the greenhouse gas carbon dioxide. In many cases the weeds have proven impossible to control even with chemicals and increased tilling and, in a seeming anachronism in the highly mechanized environment of American agriculture, farmers must hire labourers to manually weed crops. In short, the collapse of the Roundup Ready (RR) system is causing a 30-year throwback in agricultural practices

in a large and growing portion of the US, especially in southern areas where cotton and soya are major crops.

None of the glyphosate-resistant weeds that have emerged in the US since RR crops were approved is more of a threat than Palmer amaranth (*Amaranthus palmeri*) or Palmer pigweed, as it is commonly known. The unfolding Palmer pigweed disaster reveals fatal shortcomings of large-scale farming of GE herbicide-resistant crops, and how corporate greed and short-sightedness have accelerated the “chemical treadmill”.

American farmers embraced RR crops because they were far simpler to farm than other seeds, often requiring only a single herbicide – glyphosate. But the tradeoff with GE herbicide resistance has proved to be a bad one. In exchange for a few years of simplified weed control, America now has a long-term ecological headache. A formerly effective herbicide is now rapidly becoming useless in many applications, ultimately causing a throwback to expensive and even more environmentally-damaging farming methods. It is a severe indictment of one company, Monsanto, and how it was permitted to run amok with patents and control over seed companies to its financial benefit, and to the detriment of others.

It is thus a cautionary tale for countries around the world about the ecological and environmental damage that can be rendered by crops genetically engineered to resist herbicides. Palmer pigweed problems will continue across the US cotton belt in 2010 and spread to new areas and crops. Written as farmers are planting in the US for the 2010 season, this paper introduces the emergence of glyphosate-resistant Palmer pigweed to date, including its spread, what is known of its genetics, and the response of farmers, companies and agricultural extension.

## Chapter 2

# The Emergence of Glyphosate Resistance

Herbicide-resistant weeds are a global problem documented in at least 60 countries.<sup>1</sup> The severity and area affected by each instance of herbicide resistance, however, is highly variable. Some resistant weed types have only been documented in one or a few fields, while others cover large acreage and cross international borders.

Similarly, in conventional farming systems, some types of resistant weeds are easily controlled while others are more difficult to get rid of. For example, some can be directly controlled by alternative herbicides during the growing season. In other cases, resistant weeds can be controlled (or even eliminated) by applications between plantings.

Alternative herbicides or agricultural practices in conventional crops often can mitigate or control herbicide resistance. With crops that are genetically engineered to be resistant to a particular herbicide, however, the seed and the herbicide are linked in such a way that it can make control of resistant populations more difficult.

For example, if a farmer rotates between two different crops (e.g., maize and soya) and can apply herbicides with different modes of action (or use varying agricultural practices, such as



off-season cover crops to prevent weed germination), herbicide resistance may be more easily controlled. Farmers growing just one herbicide-resistant crop, or alternating between two crops resistant to the same herbicide, however, have fewer options for controlling resistance.

In addition, constant exposure to a single herbicide creates conditions that make it more likely not only for resistant weeds to survive, but for resistant populations to develop in the first place. RR crops produced by Monsanto and its licensees are resistant to the herbicide glyphosate. It has long been argued by critics that the massive and long-term use of glyphosate that RR seed has engendered would place evolutionary pressure on weeds to develop resistance to the herbicide.

As planting of multiple species of RR crops accelerated in the US in the 2000s, this pressure increased. For example, in large areas of the American South, farmers frequently rotate cotton and soya, both of which are frequently RR. Thus weeds are exposed to multiple doses of glyphosate every year.

Monsanto initially dismissed its critics by saying they were wrong about science. It then escaped public accountability when early warning signs appeared in the form of isolated reports of weeds resisting glyphosate associated with cultivation of its RR crops. While critics saw a ticking time bomb, the company claimed these were merely isolated cases that could be managed, declaring in 2004 that “The development of resistance to glyphosate is less likely compared to other herbicides”.<sup>2</sup>

In 2010, however, the company can no longer shake off the widespread resistance to glyphosate that has clearly come about as a result of the overuse of the herbicide due to the widespread planting of RR seeds.

Globally, populations of 18 weed species have been found to be glyphosate-resistant. Of these, 10 have been found in the US, in a total of 24 of its 50 states. Unofficially, information from farmers and agricultural extension agents indicates that some glyphosate-resistant species, such as horseweed (*Conyza canadensis*, also called marestail), are moving faster than the weed scientists can track them.

None of the glyphosate-resistant weeds that have emerged in the US is believed to be more of a threat to agricultural productivity than Palmer amaranth (*Amaranthus palmeri*) or Palmer pigweed, as it is commonly known. Since first being identified in 2005 in a remote area of the state of Georgia,<sup>3</sup> glyphosate-resistant Palmer pigweed has rampaged across the US South and into the Midwest, leaving abandoned fields and massive use of herbicides in its wake.

Documented in eight states, the resistant pigweed is actually in many more. Glyphosate resistance stretches in a chain of pockets across the southern tier of US states from Georgia to New Mexico, a distance of about 2,300 kilometres. Some pockets of resistant Palmer pigweed are huge, such as the 48 contiguous counties that comprise most of the southern half of the state of Georgia, all with confirmed resistant populations.<sup>4</sup>

Resistant populations of Palmer pigweed are spreading northward into states such as Kentucky, Missouri and North Carolina, facilitated by extremely high rates of adoption of RR crops. For example, in 2009 only two US cotton-producing states sowed less than 96 percent transgenic cotton (Texas and California, with 90.4 percent and 89.1 percent, respectively), the vast majority of which was Roundup Ready.<sup>5</sup>

Some of these areas are already plagued by glyphosate-resistant horseweed and waterhemp (*Amaranthus rudis* and/or *Amaranthus tuberculatus*).<sup>6</sup> Palmer pigweed hybridizes with the latter, raising the possibility of synergistic resistance. Transfer of herbicide resistance traits between waterhemp and Palmer pigweed has been demonstrated in the laboratory (see ALS resistance, below).<sup>7</sup>

What is scientifically confirmed to date is startling. In 2009, several US states each reported tens or hundreds of thousands of acres (1 acre = .405 hectare) infested with glyphosate-resistant Palmer pigweed. Resistance is moving so fast, however, that there are no reliable national estimates.

It is certain that the actual infestations in 2009 and what is unfolding again in 2010 are far worse than the confirmed statistics, and documenting it will occupy weed scientists for years to come. In Arkansas, for example, agricultural extension gave up trying to closely track the resistance as early as 2008, declaring that “The problem is so widespread that we are not going to look at all the fields or try to sample them all anymore.”<sup>8</sup>

“Officially, we have no resistance in this area, but unofficially, let me tell you, we do,” one Louisiana farmer recently told the US farm press,<sup>9</sup> which routinely reports on resistance problems in places where it is yet to be formally confirmed. Normally conservative weed scientists are openly predicting the situation to radically worsen. In early 2010 a prominent Australian scientist who has long studied US herbicide use declared, “Glyphosate will be driven to redundancy... [resistance] is at the outset of being an epidemic – it’s under way in the South with Palmer pigweed and will explode much more in the South and move further to the north.”<sup>10</sup>

To date, the weed is most problematic in cotton, but it is worsening in soya. In 2009 in Mississippi, one farmer – unlikely the only one – ploughed his soya crop under in a desperate attempt to stop the weed’s spread, “after I threw everything I could at them and couldn’t control them.”<sup>11</sup>

## Chapter 3

# What is Known About the Biology of Palmer Pigweed Resistance

Palmer pigweed is highly prolific and its range as a weed is expanding. Its pollen is distributed by wind, and each female plant grows a long, flower-covered panicle that can produce up to half a million seeds. While it is found from coast to coast of the US and as far north as Ontario, Canada,<sup>12</sup> it is a crop weed primarily in the US South, although there is evidence that it is progressively becoming a greater agricultural problem further north.<sup>13</sup>

Palmer pigweed is a dioecious species. This means that, like humans, individual pigweed plants produce only one gamete.<sup>14</sup> Palmer pigweed is therefore not self-fertile and, from an early stage, it was likely that the genetic mechanism for resistance was carried by the wind – in pollen. This, along with its profuse seed production, which can be carried on equipment and by other means, likely accounts for the rapid spread of resistance.

Glyphosate works by interrupting a plant enzyme called EPSPS,<sup>15</sup> resulting in a breakdown of production of amino acids necessary for plant health. How did the weed overcome this to not only survive glyphosate, but not even show any symptoms of damage when sprayed with seven times the normal rate of glyphosate?<sup>16</sup>

The first study on glyphosate-resistant Palmer pigweed determined that the source of resistance was not a change in ploidy<sup>17</sup> – that is, that resistance did not come from duplication of the chromosome containing the gene that produces the target enzyme, making the plant produce more enzyme than normal doses of the herbicide can block, because it has extra chromosomes.

An alternative possibility was that the production of EPSPS was increased in resistant Palmer pigweed through greater activity of the EPSPS gene. This phenomenon is thought to be the source of glyphosate resistance in some populations of ryegrass (*Lolium rigidum*).<sup>18</sup> But this too did not turn out to be the driver of resistance.

The mechanism of glyphosate resistance in Palmer pigweed was finally identified in a 2010 publication.<sup>19</sup> Rather than multiplying chromosomes or a more active EPSPS gene, it turns out that glyphosate resistance in Palmer pigweed stems from gene amplification. What this means is that there are more copies of the EPSPS gene in resistant plants than susceptible ones – five to 160 times as many copies.

Moreover, it was found that the gene copies are active and spread across the genome.<sup>20</sup> In other words, the profusion of EPSPS gene copies in resistant Palmer pigweed provides more targets than the glyphosate can block, meaning that even if glyphosate blocks some copies of the EPSPS gene, other copies function as normal and glyphosate fails to kill the plant. The findings are further confirmation of what common sense and previous science indicated: The resistance is heritable and spreading via pollen.

## Chapter 4

# Chemical Storm: The Response to Glyphosate-Resistant Pigweed

*“I continue to see growers who are just spraying Roundup in Roundup Ready cotton. If you continue to do that, you will not survive. Even if you’ve survived this far, you will not survive in the future. You have got to use residual herbicides... And of course, the plowing and the hand weeding have become much more common with the advent of glyphosate-resistant Palmer amaranth pigweed.”*

— Stanley Culpepper, University of Georgia (2009)<sup>21</sup>

What are American farmers doing in response to glyphosate-resistant Palmer pigweed? Put simply, they are using more herbicides and turning over their soil more, thereby incurring higher production costs and increasing their environmental impact. In some cases, they are also hand-weeding their crops or have abandoned fields as a result of severe infestation. Some soya farmers are adopting glufosinate-resistant “Liberty Link” seeds, as Palmer pigweed has yet to develop resistance to the herbicide glufosinate.

Tall palmer pigweed will not only compete with crops, potentially reducing yields, it can also jam farm equipment, meaning that the weeds must be removed in order to harvest the crop at all. In some cases, desperate farmers are using “rescue treatments”

(extra, often off-label use of herbicides, especially in late season) and other non-recommended chemical practices to try to contain out-of-control Palmer pigweed populations.

“Rescue treatments” include applying glufosinate to “Widestrike” cotton varieties.<sup>22</sup> Widestrike cotton, from Dow Chemical, includes genetically engineered Bt toxin genes that cause the plant to resist certain caterpillar pests. This pest resistance has nothing to do with Palmer pigweed. The Widestrike varieties are “stacked” with a Roundup Ready gene, which is their intended mechanism for weed control. A glufosinate resistance gene, however, was used as a genetic marker in developing Widestrike varieties. The herbicide resistance this gene confers is limited. Widestrike plants are still damaged by glufosinate, but this damage does not typically reduce yield.<sup>23</sup> Thus, even though this glufosinate resistance was not intended as a commercial trait, farmers who are unable to control Palmer pigweed with glyphosate are spraying Widestrike/RR cotton with glufosinate. This off-label herbicide use is not illegal in the US, but is not endorsed by either Dow or Bayer (maker of glufosinate).

Glyphosate-resistant Palmer pigweed has the upper hand on farmers and is new enough, and spreading fast enough, that few standard practices have emerged for controlling it. Scrambling to respond to farmers’ problems, university weed science programmes and the cotton industry have made a variety of recommendations that primarily take the strategy of using additional herbicides. In some areas, recommendations are particularly difficult because Palmer pigweed populations are resistant not only to glyphosate, but also to ALS herbicides (acetolactate synthase inhibitors, such as “Staple”) and photosystem II inhibitors (such as diuron).



Thus, due to resistant Palmer pigweed, the formerly simple herbicide programmes used with Roundup Ready cotton and soya have given way to weed control regimes that are far more complex and costly – for farmers and the environment:

**Syngenta's Chemical Mix:** In Roundup Ready cotton with glyphosate-resistant Palmer pigweed infestation, Syngenta unashamedly recommends that farmers use a chemical onslaught of no less than seven different “modes of action” (i.e., herbicides) in a single growing season. It says farmers should first apply paraquat mixed with a “residual” photosystem II inhibitor (its brand is “Caparol”) that is persistent in the soil. After that, Syngenta recommends applying “Reflex” (fomesafen sodium, a protoporphyrin oxidase inhibitor) mixed with “Prowl”, the company's dinitroaniline herbicide. Then, as the crop matures, Syngenta suggests first spraying glyphosate mixed with S-metolachlor, followed by trifloxysulfuron, followed by trifloxysulfuron and prometryn. Finally, shortly before harvest, the company recommends making another application of glyphosate.<sup>24</sup>

Syngenta calls it an “excellent diversity of modes of action”; but if the farmer has any energy left after mixing and applying all those chemicals, s/he very well might be lamenting an empty wallet, not to mention the potential environmental and health impacts that would ensue. Others advising on how to combat resistance have offered similar (if typically slightly less intense) recommendations to increase herbicide use.

Monsanto also recommends increased herbicide use: “We’re recommending that farmers use residual herbicides and approach every field proactively,” says Rick Cole, a Monsanto manager.<sup>25</sup> The company offers rebates on Roundup Ready cottonseed costs to farmers who supplement glyphosate with what the company terms a “more complete” use of chemicals.

These include metolachlor, flumioxazin and other herbicides, some of which are even produced by rival Syngenta. Monsanto calls the financial programme “Performance Plus”, although it is the result of the performance failure of glyphosate to control Palmer pigweed. To get the refunds, farmers must buy the extra chemicals from one of Monsanto’s own dealers.

## THE BENEFITS OF ROUNDUP READY® COTTON PERFORMANCE PLUS

The Roundup Ready® Cotton Performance Plus is simple.

- Plant cotton varieties containing either Roundup Ready® or Genuity™ Roundup Ready® Flex technology.
- Purchase qualifying residual herbicides from an authorized Monsanto retailer from 1/4/2010 thru 8/16/2010. [See Chart Below]
- Submit completed Roundup Ready® Cotton Performance Plus rebate form along with your herbicide invoices. These must be postmarked by 8/31/2010.

Use the appropriate Residual Herbicide at the Right Timing™

APPLICATION TIMING	HERBICIDE	REBATE
PRE-PLANT, PRE-OR IN-CROP	Valor	\$2.50/A
	Reflex	\$3.50/A
	Diuron®	\$1.00/A
	Cotoran	\$2.50/A
EARLY POST	Dual Magnum	\$3.00/A
LAYBY	Residual from list above	
TOTAL OPPORTUNITY		\$12.50

\* From a list approved by Monsanto.  
\*\* Rebate can be earned only once for each herbicide.

### Key Benefits

- Supports a more complete weed management system.
- Helps manage the problem of glyphosate-resistant Palmer pigweed.
- Provides rebates for qualified residual herbicides.

**PERFORMANCE FAILURE:** Monsanto promotional material for its “Performance Plus” programme to encourage use of additional herbicides on Roundup Ready cotton (<http://www.genuity.com>)

**Return of Paraquat:** A dangerous herbicide whose use is rebounding in cotton is paraquat, sometimes referred to by the trade name gramoxone. Long banned in a number of countries including Sweden (1983) and Malaysia (2002), paraquat’s registration in Europe was revoked by the European Communities Court of Justice in 2007.<sup>26</sup>

Primarily sold by Syngenta, paraquat is one of the herbicides whose use RR crops was supposed to reduce. Paraquat use is rising both as a “burn-down” herbicide (to clear a field after harvest or well before planting) as well as during the growing season, when it is applied between rows with hooded sprayers designed to coat the ground but prevent the chemical from coming into contact with the crop (which it will damage or kill).

Paraquat and another older herbicide, 2,4-D, have been recommended practically everywhere Palmer pigweed is found for burn-down application. Earlier season hooded sprayer use in areas where Palmer pigweed is resistant to both glyphosate and ALS herbicides has been endorsed by both the University of Georgia<sup>27</sup> and Cotton Inc., the research and promotion organization of the US cotton industry.<sup>28</sup>

## Chapter 5

# **Costs to Manage Glyphosate-Resistant Pigweed**

Just as glyphosate-resistant Palmer pigweed is spreading faster than it can be physically tracked, agricultural economists and weed scientists have not produced consistent data on its costs to farmers, although it is clear that they can be severe.

A variety of strategies are being employed, and these vary by region and degree of infestation. Hand weeding, an increasingly common tactic in both the southeast (e.g., Georgia) and along the southern half of the Mississippi River, is usually an expensive last resort after chemicals have failed. In 2004, hand weeding of cotton in Georgia was non-existent, but by 2008, more than 40 percent of cotton farmers manually chopped down Palmer pigweed.<sup>29</sup> The following table presents some public estimates of the cost:

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### Reported Costs of Controlling Glyphosate-Resistant (GR) Palmer Pigweed

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Location	Crop	Cost (US\$/hectare)	Source
Southern US	Cotton	\$190	Industry estimate (Cotton Inc.), includes \$130 in herbicides plus \$60 higher tillage costs.
Georgia	Cotton	\$64 (labour only)	Average cost to manually remove GR pigweed from fields, University of Georgia survey 2009.
Arkansas	Cotton	\$69 (chem. only)	Cost of extra herbicides to control GR pigweed in Arkansas cotton, Cotton Inc. 2010 Est.
Georgia	Cotton	\$64 (chem. only)	Cost of extra herbicides to control GR pigweed in Georgia cotton, Cotton Inc. 2010 Est.
Tennessee	Cotton	\$61-\$74 (chem. only)	Additional herbicide cost to control GR pigweed, Univ. of Tennessee in <i>Commercial Appeal</i> (Memphis, TN), 26 Feb 2010.
South Carolina	Cotton	\$148	Additional cost over glyphosate-only weed control, Clemson Univ. extension in <i>Southeast Farm Press</i> , 20 Sep 2006.
Mississippi	Soya	\$74	Farmer in <i>Delta Farm Press</i> , 12 Jan 2010.

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Calculating the total cost to farmers of glyphosate-resistant Palmer pigweed is difficult because of the rapidly expanding epidemic and the tentative nature of estimates of acreage infested. Using the costs per hectare cited above, an indicative range of estimates of the cost to US cotton farmers can be generated.

In 2010 the US National Cotton Council estimates that approximately 3.89 million hectares of cotton will be planted in areas where glyphosate-resistant Palmer pigweed may be a factor.<sup>30</sup> Reported costs to control glyphosate-resistant Palmer pigweed range from \$61 to \$190 per hectare. Thus:

Acreage Infested	Total cost in 2010 (US\$ million)		
	@\$61/ha	@\$100/ha	@\$190/ha
389,000 ha (10% of cotton acreage)	23.7	38.9	73.9
972,500 ha (25%)	59.3	97.3	184.8
1,945,000 ha (50%)	118.6	194.5	369.6
2,917,500 ha (75%)	178.0	291.8	554.3

While the above figures are necessarily imprecise due to the rapidly expanding problem, they do give a notion of the severity of the economic impact, particularly as glyphosate-resistant Palmer pigweed continues to proliferate.

## Chapter 6

# Impact of Increased Tilling

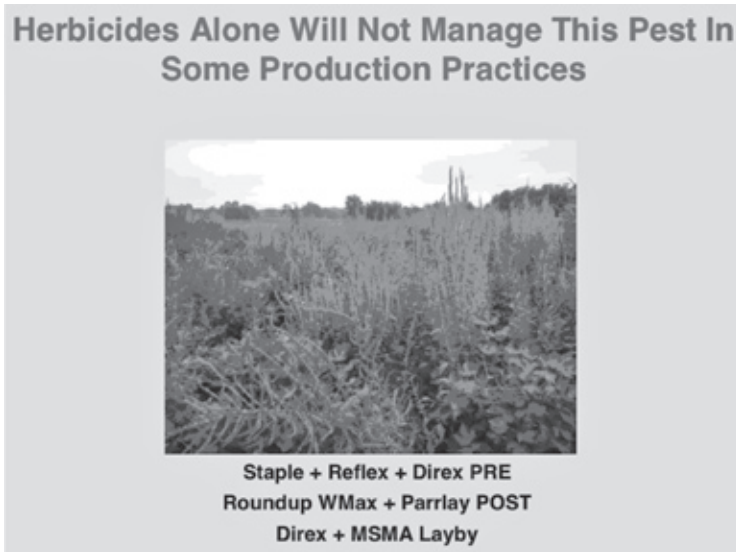
In addition to more use of herbicides and hand weeding, farmers are abandoning conservation tillage and “no-till” farming techniques. Instead, they are ploughing their fields more often to control glyphosate-resistant Palmer pigweed.

In 2008, about 20 percent of Georgia cotton farmers deep ploughed their fields, up from virtually none in 2004. In the same time frame, the percentage of Georgia farmers using strip tillage – a type of conservation tillage – fell from over 80 percent to about 45 percent.<sup>31</sup> (Note that these figures indirectly suggest that a high proportion of Georgia cotton has Palmer pigweed problems.)

The costs of increased tillage are both environmental and economic. They include fuel and wear and tear on machinery, as well as topsoil loss, which both reduces fertility and may diminish water quality (runoff) or air quality (dust).

While it preserves topsoil and (normally) reduces trips across the field, conservation tillage has come under fire for increasing the use of herbicides. Land that has not been turned over for many years may require (in conventional farming) relatively high use of herbicides to prevent weeds from getting out of control outside the growing season.

Thus, under normal expectations, the cost of reducing conservation tillage – increased use of gasoline, equipment, and higher greenhouse gas emissions – would be in some respects offset by a reduction in the use of herbicides because, under normal circumstances, ploughing would reduce the need for those chemicals.



Slide showing RR cotton overwhelmed by Palmer pigweed, despite use of six different herbicides. (University of Georgia presentation to cotton extension agents, 2010)

With glyphosate-resistant Palmer pigweed, however, this does not appear to be the case. Rather than reducing herbicide recommendations in conjunction with increased tilling, turning the ground over more is being treated as just another weapon against glyphosate-resistant Palmer pigweed, and does not appear to have any concomitant downward effect on herbicide use recommendations. In fact, because of glyphosate resistance, increased tillage is frequently part of an overall package of increased chemical use.



## Chapter 7

### **Cloudy Outlook: 2,4-D- and Dicamba-Resistant Cotton**

With RR cotton rapidly ceasing to be useful to control Palmer pigweed across the US cotton belt and, increasingly, in soya, there are no new herbicidal modes of action coming to market for use on cotton. Caught in a bind, conventional farmers are looking for new solutions. Some are battling with herbicides and manual labour, and some have returned to tillage and/or non-GE cotton varieties. In the short term, Bayer and Syngenta are promoting Liberty Link cotton and soya varieties which are resistant to the herbicide glufosinate while, at the same time, encouraging Roundup Ready farmers to use heavy chemical applications.

Glufosinate has a different mode of action than glyphosate. For the short term, it offers a Roundup Ready-like herbicide system, for both cotton and soya, that is effective on glyphosate-resistant Palmer pigweed. Liberty Link crops, however, have been adopted to a far lesser extent than RR crops by American farmers. Although glyphosate resistance is tipping the balance in Bayer's and Syngenta's favour, the Liberty Link system shares key weaknesses with RR, and the emergence of glufosinate-resistant weeds is likely only a matter of time if it is widely adopted.

With no new herbicides emerging, companies are turning back the clock to engineer resistance to old chemicals into new seeds

– perpetuating, even increasing, the use of chemicals such as 2,4-D (an ingredient of the Agent Orange defoliant used in Vietnam) and dicamba well into the future.

Dow Chemical recently confirmed its work on 2,4-D-resistant seeds, which it claims it will bring to market as early as 2012 in maize, 2013 in soya, and 2015 in cotton.<sup>32</sup> Long a target of environmental and pesticide campaigners, 2,4-D is banned in some European countries and its use restricted elsewhere. Monsanto is developing GE cotton and soya resistant to dicamba, another older agricultural chemical. Dicamba and 2,4-D have similar modes of action, and 28 weed species have already been documented to have resistance to one or more herbicides from this family.<sup>33</sup> Both companies say they plan to stack these new resistance traits with glyphosate or glufosinate resistance.

## Chapter 8

### Conclusion

The rapid spread of glyphosate-resistant Palmer pigweed constitutes a major agronomic failure of genetically engineered Roundup Ready seeds. This failure was foreseen by critics but dismissed by Monsanto. The critics were right. The failure is prompting US farmers to revert to agricultural practices used in the 1980s and earlier, such as hand weeding and increased tillage.

Stricken by a lack of foresight across the conventional agricultural sector, farmers have little choice but to increase use of herbicides, including older chemicals banned in many countries due to their toxicity. These include paraquat and 2,4-D, both of which many environmental and health campaigners have long urged to be more tightly regulated or simply prohibited.

Lacking a new approach, agrochemical giants are responding by trying to pump their herbicide sales, and with more of the same flawed genetic engineering approach of herbicide-resistant crops. They are creating seeds that are resistant to older chemicals, which will inevitably result in wider use of these problematic herbicides. These environmentally damaging strategies are doomed to failure.

Far from bringing American cotton farmers into a new, gilded biotech age, the price of Monsanto's profits and overreliance on glyphosate is an expensive unfolding chemical catastrophe that is leading US farmers right back to where they started: hoes, ploughs, unsustainable reliance on toxic chemicals, and unacceptable environmental impacts.

# Endnotes

- <sup>1</sup> International Survey of Herbicide Resistant Weeds. URL: <http://www.weedscience.org>
- <sup>2</sup> Monsanto (2004). Investigations Continue on Isolated Case of Difficult to Control Common Ragweed in Missouri (news release). 7 July.
- <sup>3</sup> Culpepper AS et al. (2006). Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) confirmed in Georgia. *Weed Science* 54:620.
- <sup>4</sup> Culpepper AS et al. (2010). University of Georgia Programs for Controlling Moderate to Severe Populations of Glyphosate-Resistant Palmer Amaranth in 2010 Cotton. University of Georgia Cooperative Extension.
- <sup>5</sup> USDA Agricultural Marketing Service (2009). Cotton Varieties Planted 2009 Crop. August.
- <sup>6</sup> These two closely related species have shown many forms of herbicide resistance. Sometimes called “common waterhemp” and “tall waterhemp” respectively, some botanists argue that they should be considered a single species (Pratt DB and LG Clark (2001). *Amaranthus rudis* and *A. tuberculatus* – One species or two? *Journal of the Torrey Botanical Society* 128:3). Some scientists treat them as one, while others maintain a species distinction.
- <sup>7</sup> Wetzel D et al. (1999). Transferal of herbicide resistance traits from *Amaranthus palmeri* to *Amaranthus rudis*. *Weed Science* 47:538-543.

- <sup>8</sup> Scott B (2008). Palmer pigweed getting revenge. *Delta Farm Press*. 29 July. (Scott is a University of Arkansas weed scientist.)
- <sup>9</sup> Robinson E (2010). Cotton producers worry about costs. *Delta Farm Press*. 14 April.
- <sup>10</sup> Bennett D (2010). Powles: weed resistance will worsen. *Delta Farm Press*. 4 March.
- <sup>11</sup> Robinson E (2010). Old technology coming out the closet. *Delta Farm Press*. 12 January.
- <sup>12</sup> USDA (2010). NRCS Database of Plants of the United States and its Territories (website). URL: <http://plants.usda.gov/index.html>
- <sup>13</sup> Holshouser D et al. (2009). Palmer Amaranth Control in Soybean: 2009 Efficacy Experiments. Virginia Cooperative Extension. URL: <http://pubs.ext.vt.edu/2912/2912-1429/2912-1429.html>
- <sup>14</sup> In other words, in human equivalent terms, individual Palmer pigweed plants produce either sperm (pollen) or eggs (embryos), but not both (as many plants do).
- <sup>15</sup> EPSPS is an abbreviation for 5-enolpyruvylshikimate-3-phosphate synthase.
- <sup>16</sup> Bennett D (2008). Resistant pigweed 'blowing up' in Mid-South. *Delta Farm Press*. 30 July.
- <sup>17</sup> Culpepper AS et al. (2006). Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) confirmed in Georgia. *Weed Science* 54:620.

- 18     Gaines TA et al. (2010). Gene amplification confers glyphosate resistance in *Amaranthus palmeri*. *PNAS* 107:3.
- 19     Ibid.
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The widespread planting of “Roundup Ready” crops that are genetically engineered to be resistant to the herbicide glyphosate has led to the emergence of glyphosate-resistant weeds in fields in the United States. Of these weeds, the species believed to pose the greatest threat to agricultural productivity is Palmer amaranth – more commonly known as Palmer pigweed – which has infested cotton and soya farms across the southern US and is expected to spread to new areas and crops.

The approach currently adopted to stem its spread has been to apply more and more herbicides, including chemicals which are banned in many countries due to their toxicity. American farmers have also had to revert to agricultural practices used in the 1980s and earlier, such as hand weeding and increased tillage. Such measures will not only push up farm production costs, but give rise to adverse environmental impacts as well.

This paper examines the worrying extent and implications of the Palmer pigweed problem, which the author says shows up the folly of US agriculture’s increasing reliance on genetically modified herbicide-resistant crops.

**Edward Hammond** is an American policy researcher who has worked on biodiversity, biological weapons and infectious disease issues since 1994. From 1999 to 2008 he directed the Sunshine Project, an international non-governmental organization specializing in biological weapons control. Hammond was Programme Officer for the Rural Advancement Foundation International (now the ETC Group) from 1995 to 1999. He holds MS and MA degrees from the University of Texas at Austin, USA, where he was an Inter-American Foundation Masters Fellow.

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