



HERBICIDE RESISTANT CROPS

The Truth About the World's Most Widely
Grown **Genetically Engineered** Plants



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1.0 INTRODUCTION

1.1 What is Genetic Modification?

Genetic modification (GM) or genetic engineering (GE) is a relatively new technology for conferring new properties or traits on organisms. GM involves the direct manipulation of genes, the basic units of heredity, and represents a radical departure from traditional plant breeding in several respects.

First, GM bypasses natural reproductive processes. Genes are transferred between completely unrelated species, such as bacteria and corn, that could never breed in nature. Second, it requires expensive laboratories, specialized expertise and many millions of dollars to implement¹ while traditional breeding is inexpensive and accessible to anyone willing to learn. Third, GM is a new and still primitive technology that gives rise to many unintended and unpredictable effects in plants,² some potentially hazardous, such as new toxins, allergens or reduced nutrition.³ In contrast, traditional breeding is safe and predictable because it is based on natural reproductive processes honed over millennia of evolution.

1.2 GM Crops: Facts on the Ground

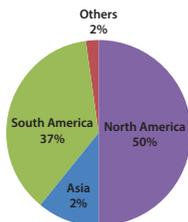
For three decades, biotechnology firms have promised to develop GM crops designed to ameliorate world hunger and malnutrition. However, the facts on the ground show that these promises remain unfulfilled.

First, GM crops are heavily concentrated in a handful of countries with industrialized, export-oriented agricultural sectors. Just eight nations in the Americas—primarily the U.S., Canada, Brazil and Argentina—accounted for 87% of GM crop acreage^a in 2011.⁴ Asian nations—chiefly India and China—are home to just 11% of GM crops with the remaining 2% grown in Australia, Africa and Europe.

Second, just four GM crops—soybeans, corn, cotton and canola—comprise 99.6% of world biotech crop acreage.^a Soybeans and corn predominate and are used primarily to feed livestock or fuel cars (as biofuels) in rich nations, not feed hungry people. India and China grow GM cotton, but little or no GM food crops. While it has been widely claimed that GM cotton has dramatically increased cotton yields in India, it turns out that these yield gains occurred mostly before GM cotton was introduced and that cotton yields have stagnated during the period of GM cotton adoption.⁵

Where are GM Crops Grown

(% of world GM acreage, 2011)

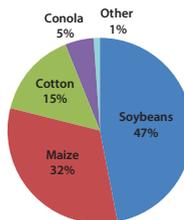


Source: International Service for Acquisition of AgriBiotech Applications (2011). "Global Status of Commercialized Biotech/GM Crops: 2011," Executive Summary, ISAAA Brief 43-2011, ISAAA. <http://www.isaaa.org/resources/publications/briefs/43/executivesummary/default.asp>

^a GM sugarbeets and alfalfa, grown only in the U.S., make up most of the remainder.

Which crops are GM

(% of world GM acreage, 2011)



Source: International Service for Acquisition of AgriBiotech Applications (2011). "Global Status of Commercialized Biotech/GM Crops: 2011," Executive Summary, ISAAA Brief 43-2011, ISAAA. <http://www.isaaa.org/resources/publications/briefs/43/executivesummary/default.asp>

Third, there are no commercial GM crops engineered for increased yield, enhanced nutrition, increased fertilizer use efficiency, salt-tolerance, “edible vaccines,” or many other attractive-sounding traits touted by industry for decades. Disease-resistant GM crops are practically non-existent.^b Instead, virtually 100% of GM crop acreage is planted to crops with just one or two traits: resistance to insects and/or resistance to herbicides (weed-killers).

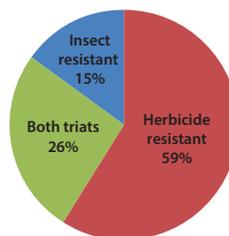
GM corn and cotton have been engineered to produce insecticides in their tissues by inserting genes derived from a soil bacterium, *Bacillus thuringiensis* (Bt). These “Bt” crops are protected from a few, but by no means all, insect pests. GM soy, corn, cotton, canola, sugarbeets and alfalfa have also been engineered with a bacterial gene (from the soil microbe, *Agrobacterium*),^c to withstand the direct application of herbicides to permit more convenient control of weeds.

1.3 Overview of Herbicide-Resistant Crops

Herbicide-resistant (HR) crops^d were planted on 136.1 million hectares in 2011,⁷ comprising an astonishing 85% of world GM crop acreage. Most of these HR crops have only an HR trait (59%) while 26% are “stacked” with insect-resistance or “Bt”. GM soybeans and canola comprise the majority of HR-only crops while all stacked GM crops are corn or cotton. Overall, crops with HR traits are more than twice as prevalent as Bt crops.

Virtually all HR crops are engineered by Monsanto for resistance to glyphosate, the active ingredient of Roundup. While these Roundup Ready varieties predominate, in 2010 Monsanto and Dow introduced “SmartStax” corn, which is resistant to both glyphosate and glufosinate; Monsanto reported 5.3 million hectares planted in the U.S. in 2011.⁸ Bayer CropScience also has glufosinate-resistant “LibertyLink” varieties of corn, cotton, canola and soybeans in the market, which are planted on roughly 0.8 million hectares in the U.S.⁹ There are a few non-GM herbicide-resistant crops—primarily Clearfield rice, canola

GM Crops by Trait(s) (% of world GM acreage, 2011)



Source: International Service for Acquisition of Agribiotech Applications (2011). “Global Status of Commercialized Biotech/GM Crops: 2011,” Executive Summary, ISAAA Brief 43-2011, ISAAA. <http://www.isaaa.org/resources/publications/briefs/43/executive-summary/default.asp>

corn and wheat—developed via a gene-scrambling technique known as mutagenesis by the German agrichemical giant, BASF.

Clearfield varieties are resistant to imidazolinone herbicides such as imazamox and imazethapyr, but, like LibertyLink, are planted very little in comparison to glyphosate-resistant crops.¹⁰ The biotechnology industry has a host of new GM herbicide-resistant (HR) crops in the pipeline, however, which are discussed further below.

Because the vast majority of HR crops are grown in the U.S., Canada and South American countries, this fact sheet draws heavily on experiences in those nations. However, the biotechnology industry has begun to introduce HR crops in Africa and Asia as well. The strategy is to transition farmers from Bt corn and cotton to stacked varieties that are also herbicide-resistant.^d For instance, most of the GM corn, soybean and cotton in South Africa are now glyphosate-resistant¹¹ while Monsanto is poised to introduce Bt/Roundup Ready cotton in India.¹² This profit-driven strategy explains why stacked crops have expanded by a substantial 15-fold over the past 12 years: from just 2.8 million ha in 1999 to 42.2 million ha in 2011.¹³

b GE virus-resistant papaya and squash are grown on miniscule acreage in the U.S. only.

c Industry prefers to use the term “herbicide-tolerant,” presumably because “tolerant” has positive connotations. However, this usage is incorrect. Weed scientists have officially defined crops of this sort as “herbicide-resistant.” See Anonymous (1998), “Technology Notes,” *Weed Technology* 12(4): 789-90.

d This follows the strategy Monsanto pursued in the U.S. The company first introduced Bt corn and cotton, then rapidly replaced the Bt-only varieties with stacked versions. Today, a great majority of GM corn and cotton in the U.S. is both Bt and Roundup Ready.

2.0 IMPACTS OF HERBICIDE-RESISTANT CROPS

2.1 “Farming Without Farmers”

The chief attraction of HR crops to farmers is making weed control more flexible, simpler, and less labor-intensive.¹⁴ The herbicide-resistance trait allows the associated herbicide to be applied through much or all of the season without damaging the crop whereas the same herbicide can only be applied before planting or seed-sprouting with conventional crops. In the case of Roundup Ready (RR) crops, glyphosate is extremely “broad-spectrum,” meaning it kills a wider array of weeds than most herbicides. Thus, farmers often rely exclusively on glyphosate with RR crops. This is more convenient and saves time compared to conventional weed control, which often involves multiple herbicides and other weed control practices. As discussed below, however, the simplicity of Roundup-only weed control has fostered an epidemic of glyphosate-resistant weeds that are rapidly eroding these benefits, leading to much more complex and labor-intensive weed control practices.

The labor-saving feature of RR crop systems has made them particularly well-suited to the large, industrial farming operations of North and South America. Labor-saving is extremely important to large industrial farmers, often more important than yield. For instance, Gustavo Grobocopatel, whose operations cover 200,000 acres of soybeans in Argentina (an area the size of New York City), prefers to plant Roundup Ready varieties for the sake of simplified weed control, even though he obtains consistently higher yields with conventional soybeans.¹⁵

The ability to farm more land with the same labor has facilitated the rapid expansion of Roundup Ready soybean monocultures in South American nations. This has led to the displacement of small farmers who grow food crops for local consumption, which both disenfranchises them and contributes to food insecurity. In Argentina, the production of potatoes, beans, beef, poultry, pork and milk have all fallen with rising GM soybean production while hunger and poverty

have increased.¹⁶ In Paraguay, the poverty rate increased from 33% to 39% of the population from 2000 to 2005, the years in which huge soybean plantations (about 90% of them now GM soybeans) expanded to cover over half of Paraguay’s total cropland.¹⁷

According to the Argentine Sub-Secretary of Agriculture, the labor-saving effect of RR soybean systems means that only one new job is created for every 500 hectares of land converted to GM soybeans.¹⁸ This same amount of land, devoted to conventional food crops on moderate-size family farms, supports four to five families and employs at least half a dozen. The Argentine government has acknowledged that this trend to “agricultura sin agricultores” (farming without farmers) is harmful,¹⁹ but it is not clear that anything is being done to address it.

A similar trend is evident in the U.S., where much farmland is leased rather than owned. Large farmers growing RR crops seek to expand, bidding up the price for leased land. Small farmers who cannot afford to renew their leases must sacrifice their land to larger farmers who have the means to do so.²⁰



Crops are being sprayed with pesticides

Thus, Roundup Ready crops facilitate the worldwide trend of concentrating farmland in fewer, ever bigger farms. Small farmers are pushed off the land, exacerbating the social problems of displacement and poverty. Developing nation leaders should carefully consider this evidence before deciding whether or not to embrace biotech agriculture.

2.2 Herbicide Resistant Crops Increase Herbicide Use

The most reliable independent assessment of pesticide use^e with GM crops to date was conducted by Dr. Charles Benbrook, former Executive Director of the Board on Agriculture of the U.S. National Academy of Sciences. Dr. Benbrook utilized gold-standard pesticide usage data from the USDA's National Agricultural Statistics Service to assess how the introduction of the major GM crops in the U.S. (soybeans, corn and cotton) has affected pesticide use since their introduction in 1996. Benbrook found that Roundup Ready crops increased herbicide use by a massive 239 million kg over the 16 years from 1996-2011 versus what would have been used had they not been introduced.²¹

There are two basic reasons for this increase. First, Roundup Ready crops drove a massive increase in agricultural use of glyphosate, from just 25-30 million lbs. in 1995 to 180-185 million lbs. in 2007, the latest year for which US Environmental Protection Agency (EPA) data is available.²² And while glyphosate did displace other herbicides, most of those displaced were "low-dose" weed-killers' flower rates than glyphosate. Second, farmers gradually applied more of both glyphosate and other herbicides in response to the growing epidemic of glyphosate-resistant weeds.

Benbrook's assessment is confirmed by USDA data on pesticide use (see Figure 1), which shows sharply increasing overall herbicide use on soybeans and cotton since 2001 and a more modest rise for corn since 2002.

Benbrook has also debunked several "simulation studies" of herbicide use on Roundup Ready crops conducted by biotechnology industry front groups.²³

He showed that the authors employed false assumptions to suggest reduced use of herbicides with RR crops, results that are undoubtedly fallacious because they cannot be reconciled with gold standard USDA data which demonstrate conclusively that herbicide use has increased substantially during the Roundup Ready era. Hence a technology often fraudulently promoted as moving agriculture beyond the era of chemicals has in fact increased chemical dependency. And of course, expensive inputs like herbicides are beyond the means of most poor farmers, especially in combination with expensive GM seeds.

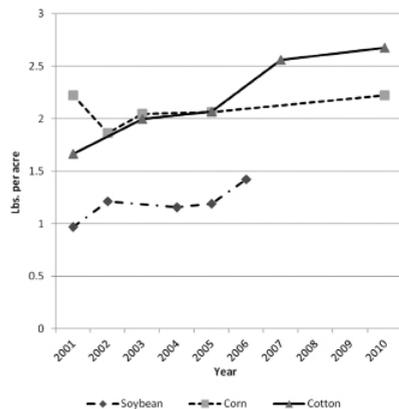


Figure 1. Intensity of herbicide use on major field crops in the U.S.: 2001-2010

Source: "Agricultural Chemical Usage: Field Crops Summary," USDA National Agricultural Statistics Service, for the respective years. USDA does not collect data every year for each crop. For instance, no soybean data has been collected since 2006, and no corn data was collected from 2006 to 2009. 2010 corn and cotton data in USDA-NASS AgChem (2010). <http://usda.mannlib. soybeanell.edu/MannUsda/viewDocumentInfo.do?documentID=1560>

2.3 Herbicide-Resistant Crops and Weeds

Herbicide-resistant crops can only be properly understood as weed control systems that closely tie the use of a particular herbicide to the crop in question. Several features of HR crop systems (discussed below) make them very prone to trigger the rapid evolution of resistant weeds, a serious and rapidly growing problem in North and South

^e Pesticides are any pest-killing chemicals, and include not only insecticides, but also herbicides, fungicides, nematocides and others.

^f The weedkillers that glyphosate displaced are "low-dose" (always used at ten-to-thousand-fold lower rates than glyphosate).

American nations where HR crops are widely grown. Resistance is not created by herbicide use per se. Rather, certain individual weeds have the rare genetic predisposition (mutation) that permits them to survive exposure to an herbicide that kills the vast majority of its species. HR crop systems promote rapid expansion of these initially rare resistant weeds by fostering frequent and late application of the herbicide, and abandonment of other weed control tactics.²⁴

Repeated use of the herbicide gives resistant weeds a competition-free environment to flourish, by killing off the majority of weeds that are susceptible to it. The abandonment of other weed control tactics (see Section 4.3) allows the resistant individuals to survive and grow. The late application of the HR crop-associated herbicide gives resistant individuals a better chance of surviving to sexual maturity and produce pollen and seeds that propagate the resistance trait. The evolution of resistant weeds occurs via the same process by which bacteria evolves resistance to over-used antibiotics.

Once an herbicide-resistant weed population is established, it can spread very rapidly by cross-pollinating susceptible weeds, sometimes over very great distances. Seeds carrying the resistance trait can likewise be transported to fields many kilometers away by wind²⁵ or via waterways when heavy rains wash the seeds into rivers.²⁶

2.3.1 Roundup Ready crops and the glyphosate-resistant weed epidemic

Glyphosate was introduced in 1974. A few isolated populations of glyphosate-resistant weeds emerged in the late 1990s, attributable to intensive glyphosate use in orchards or in wheat production.

The vast majority of glyphosate-resistant (GR) weeds, however, have emerged in RR soybeans, cotton, corn and sugarbeets since the year 2000, thanks to the massive use of glyphosate with these crops. The International Survey of Herbicide-Resistant Weeds provides the following data.²⁷ By the end of the 1990s, there were just six reports of confirmed GR weeds infesting a few

hundred fields covering 12,000 hectares in three countries. Today, there are 157 reports of GR weeds in over 240,000 fields covering more than 7 million hectares in 20 nations. Alarming as these figures may be, they are nevertheless based on an incomplete survey and underestimate the true extent of the problem. This is because weed scientists often lack the funding and resources to properly investigate GR weeds, or to update their initial findings to account for expanding weed populations. Other estimates that take these factors into account place the total area infested with glyphosate-resistant weeds at 15-24 million hectares in the U.S. alone.²⁸

The problem is worst in the U.S., where populations of 14 weed species have evolved resistance, including horseweed, Palmer amaranth (pigweed), waterhemp, giant ragweed and kochia. The most troublesome glyphosate-resistant weeds in South America are sourgrass (Paraguay & Brazil), Johnsongrass (Argentina) and several species of ryegrass.

Most resistant weed populations thus far have been driven by intensive glyphosate use associated with RR soybeans and RR cotton in the eastern and southern U.S. However, the increasing reliance on glyphosate associated with the growing use of RR soybean/RR corn rotations is driving the rapid emergence of resistant weeds in the Midwest and Northern Plain states. The latest hotspot is Minnesota and North Dakota, where GR weeds are emerging at a "truly astonishing" rate,²⁹ boosted by the 2008 introduction of RR sugar beets. This troubling trend can only accelerate in the future, especially in the absence of serious resistant weed management programs.

At present, the vast majority of RR crop acreage in South America is RR soybeans. However, Monsanto is aggressively pushing RR corn in Argentina and Brazil, just as it has done in the U.S. As more and more farmers incorporate RR corn into existing rotations with RR soybeans, the result can only be rapidly expanding glyphosate-resistant weed populations in South America. Glyphosate-resistant weeds will also crop up in Africa and Asian nations (notably India) as stacked Roundup Ready/Bt corn and cotton become more prevalent.

2.3.2 The many costs of glyphosate-resistant weeds

Glyphosate-resistant weeds have had serious adverse impacts on U.S. farmers and the environment. The U.S. National Academy of Sciences notes that farmers respond to resistant weeds by applying more of both glyphosate and other herbicides, and by increasing their use of tillage,³⁰ a mechanical means of controlling weeds that can increase soil erosion and destroy soil structure.

Dr. Benbrook estimates that 46% of the 383 million lbs (or 173,736 tonnes) of increased herbicide use attributable to Roundup Ready crops (1996-2008) occurred in crop years 2007 and 2008, which reflects rising use to control increasingly resistant weeds. This increase includes greater use of toxic herbicides such as 2,4-D and paraquat³¹ while others such as atrazine, acetochlor and S-metolachlor continue to be used at high rates despite increasing use of glyphosate.³² Dioxin-contaminated 2,4-D was a component of the toxic Agent Orange defoliant used in Vietnam and paraquat is a neurotoxic herbicide that has been linked to increased incidence of Parkinson's disease³³ as well as being a potential endocrine disruptor, teratogen, genotoxin and carcinogen.³⁴ It is also a leading cause of farmer deaths from both accidental ingestion and suicides.³⁵

Agronomists have documented substantial reduction in soil-saving conservation tillage in at least four U.S. states as farmers turn back to the plow to control glyphosate-resistant weeds at the cost of increased soil erosion.³⁶ Erosion washes both soil and agrochemicals into waterways, degrading river quality and harming aquatic life.

However, it should be noted that judicious use of tillage need not degrade soil quality, and even has some benefits including: aeration of the soil, drying out overly wet soil, and destruction of some pests as well as weeds. Tillage also incorporates crop residues. When utilized in organic farming systems, tillage can build up high levels of organic matter in the soil, which improves soil quality and inhibits erosion. In fact, a recent nine-year study by the US Dept. of Agriculture agronomists found that organic systems provide greater long-term soil benefits than conventional no-till agriculture.³⁷

Glyphosate-resistant weeds have also taken U.S. farming back to the days of hand-weeding, an ironic result of the latest in agricultural technology. In Georgia alone, farmers have resorted to weeding crews to manually hoe glyphosate-resistant pigweed on 200,000 hectares of cotton, at a cost of \$11 million.³⁸

Collectively, these responses to glyphosate-resistant weeds are extremely expensive. Some cotton farmers report a tripling or quadrupling of weed control costs due to glyphosate-resistant weeds.³⁹ Likewise, control of rapidly emerging glyphosate-resistant waterhemp in the northern state of Minnesota is estimated to raise weed control costs from roughly \$18/acre to as much as \$133/acre.⁴⁰ These expenditures are unavoidable for farmers locked into the GM-crop system since failure to control GR weeds results in dramatic yield reductions. In extreme cases, farmers, unable to control these weeds, have had to abandon their fields as they had become 'unharvestable'.⁴¹

2.3.3 New herbicide-resistant crops and the chemical arms race with weeds

The biotechnology industry is responding to the glyphosate-resistant weed epidemic by developing a host of new GM crops that are resistant to older, more toxic herbicides.⁴² Dow AgroSciences is poised to introduce 2,4-D-resistant corn, soybeans and cotton. Monsanto is not far behind with the same three crops resistant to dicamba, a close chemical cousin of 2,4-D. Both herbicides mimic plant hormones (auxins) and kill broadleaf plants by stimulating abnormal cell growth.⁴³ DuPont has both soybeans and corn resistant to ALS inhibitors, a large family of herbicides that kill both grasses and broadleaf plants by blocking the acetolactate synthase (ALS) enzyme and so preventing plants from synthesizing key amino acids. The most prominent classes of this large family of herbicides are sulfonylureas and imidazolinones; other classes include pyrimidinylthiobenzoates, sulfonylaminocarbonyltriazolinones, and triazolopyrimidines.⁴⁴ Bayer CropScience is preparing to introduce soybeans resistant to isoxaflutole, a carcinogenic member of the newest class of herbicides, known as HPPD-inhibitors. These herbicides "bleach" and kill weeds by blocking an enzyme (4-hydroxyphenylpyruvate dioxygenase or 4-HPPD) that is crucial to

photosynthesis.⁸ In most cases, these crops will be “stacked” with resistance to glyphosate. Some come with resistance to glufosinate as well.

Weeds resistant to multiple herbicides are already on the rise, with 44% having emerged since just 2005.

Most of these new HR crops will be targeted first to U.S. farmers, though they will also likely be marketed in developing nations that adopt RR crops as the rapid evolution of glyphosate-resistant weeds creates an opportunity to introduce them.

However, German agrochemical giant BASF has developed imidazolinone-resistant soybeans specifically for the South American market.⁴⁵ These soybeans would be of little use in the U.S. where weeds resistant to this class of herbicides have been prevalent since the late 1980s, due to their overuse in the era prior to Roundup Ready crops.^h In fact, the need for a new “fix” for the massive problem of imidazolinone-resistant weeds was an important factor driving U.S. farmers to adopt Roundup Ready soybeans.⁴⁶

This illustrates an important lesson. Industry presents their new HR crops as “solutions” to existing weed resistance problems. After short-term relief, at best, the massive herbicidal onslaught that will accompany this wave of new multiple herbicide-resistant crops will trigger the evolution of increasingly intractable weeds. Weeds resistant to multiple herbicides are already on the rise, with 44% having emerged since just 2005.⁴⁷

Weeds resistant to the 2,4-D class of herbicides (synthetic auxins, which includes dicamba and MCPA) are already common,ⁱ though populations tend to be small. However, studies show that widely prevalent glyphosate-resistant weeds, such as horseweed, waterhemp, Palmer amaranth and kochia, will likely evolve additional resistance to 2,4-D and dicamba when crops resistant to

these herbicides are introduced.⁴⁸ Thus, today’s “solution” creates tomorrow’s more serious problem and with it, the demand for an expensive new fix, in the form of a new HR crop. How far will this chemical resistance arms race between crops and weeds proceed?

An indication is provided by a patent awarded to biotechnology giant DuPont. DuPont envisions the development of a single crop resistant to seven or more different classes of herbicides.⁴⁹ The public health, environmental and farmer welfare impacts of the high-rate use of so many herbicides is almost inconceivable, although it makes perfect business sense to the biotechnology giants, as discussed below.

2.3.4 Herbicide-resistant weeds via cross-pollination

HR crops can also generate herbicide-resistant weeds by cross-pollinating with sexually compatible weeds. At present, however, few problematic weeds have been generated in this way, mostly because the HR crops grown thus far (soybeans, corn, and cotton) have few weedy relatives with which they can interbreed, at least in the U.S. Nevertheless, recently introduced Roundup Ready alfalfa is very likely to cause serious weed problems by passing the resistance trait to feral (wild) alfalfa, which is prevalent wherever alfalfa is grown. These feral populations will act as a reservoir for the Roundup Ready trait, which can then be passed back to conventional alfalfa. Because alfalfa is cross-pollinated by bees at distances up to several miles, this is sure to become a serious problem for conventional and organic alfalfa growers.⁵⁰

The need for a new “fix” for the massive problem of imidazolinone-resistant weeds was an important factor driving U.S. farmers to adopt Roundup Ready soybeans.

^h For the long list of weeds resistant to ALS inhibitors, see <http://www.weeds-science.org/Summary/UspeciesMOA.asp?lstMOAID=3&FnlHRACGroup=6a>.

ⁱ See <http://www.weeds-science.org/summary/MOASummary.asp>.

^g See http://en.wikipedia.org/wiki/P-hydroxyphenylpyruvate_dioxygenase_inhibitor.

2.3.5 Herbicide-resistant crops as weeds

The HR crop itself can act as a weed in the form of “volunteers” i.e., plants that sprout in subsequent seasons from seed left in the field after harvest. Volunteer Roundup Ready corn has been cited as a serious weed in RR soybean fields in the U.S., and can cause substantial yield losses if not controlled.⁵¹ Volunteer canola resistant to one or more herbicides has become a common and problematic weed in Canada,⁵² leading to greater use of herbicides and tillage.⁵³ Volunteer RR canola has recently been identified as an emerging weed in California, which will require the use of more toxic herbicides to control.⁵⁴ RR canola has never been grown commercially in California. This serious emerging weed threat arose from a 400-square meter field trial in 2007,⁵⁵ evidence of how little it takes for an HR crop to get out of control. RR alfalfa can also be a troublesome volunteer weed in subsequently planted vegetable crop fields.

As HR crops resistant to two, three and more herbicides are introduced, the “volunteers” of these crops will be uncontrollable with those herbicides. Here, too, farmers who stay locked into the GM system will resort to ever more toxic “herbicide cocktails” to control a problem of the technology’s own making.

2.4 Human Health and Environmental Harm from Herbicide Use

Scientific studies demonstrate that many pesticides (including herbicides) harm human health and the environment. This is especially true of highly hazardous pesticides, which have high acute toxicity and/or long-term toxic effects. Exposure to various pesticides is known or suspected to elevate one’s risk of many diseases, including cancer, neurological disorders, and endocrine and immune system dysfunction.⁵⁶ Epidemiological studies show that farmers in many countries have higher rates of certain cancers that are frequently linked to pesticide exposure, even though farmers have less cancer overall and are generally healthier than other groups.⁵⁷ Hormonal disruption can occur at infinitesimal exposure levels, with the unborn foetus and young children being especially vulnerable.⁵⁸ Many pesticides

that were initially declared safe and widely used for decades have had to be phased out in light of subsequent scientific studies demonstrating harm to human health or the environment.⁵⁹ Pesticides also pollute surface and ground water, harming amphibians, fish and other wildlife.

Regulators often miss the toxic effects of pesticides because their assessment procedures are deeply flawed.⁶⁰ For instance, the U.S. Environmental Protection Agency essentially ignores medical epidemiology, requires little or no testing of formulated pesticide products; fails to consider exposure to multiple pesticides and other toxins, wrongly assumes that farmers comply with unrealistic requirements to reduce exposure, and relies almost entirely on testing conducted or commissioned by the pesticide company, which has a strong financial interest in the finding of “safety.”

2.4.1 Glyphosate formulations

It is on the basis of such flawed regulatory tests that some regard glyphosate as relatively safe. However, a growing body of independent scientific evidence suggests that glyphosate products are in fact harmful to human health.

Use of glyphosate formulations has been associated with increased risk of the immune system cancer non-Hodgkin’s lymphoma (NHL) in the U.S.,⁶¹ and NHL and hairy cell leukemia in Sweden.⁶² Scientists with the U.S. National Institutes of Health found “a suggested association with multiple myeloma incidence” in U.S. pesticide applicators exposed to glyphosate formulations.⁶³ These scientists urge “ongoing risk assessment” in light of the massive increase in use of glyphosate since the study was conducted.

Other epidemiological studies suggest that Roundup and/or pesticides used with it cause birth defects in the children of those exposed to it. For example, a 2009 study found that pregnant women exposed to Roundup and other pesticides in Itapua, Paraguay where Roundup Ready soybeans are widely grown were more likely

j Regulators consider tests of the active ingredient alone, not the formulated product used by farmers (e.g. glyphosate is tested, not Roundup). Formulations contain additional ingredients to improve performance that are often toxic in their own right, or increase the toxicity of the active ingredient.

to deliver children with severe birth defects than unexposed women.⁶⁴ A study in the U.S. state of Minnesota found increased risk of neurobehavioral disorders in children of Roundup applicators.⁶⁵ A 2007 study in Ecuador found a higher degree of DNA damage in people living in an area that was aerially sprayed with Roundup than in a control group not exposed to the herbicide.⁶⁶ DNA damage can give rise to cancer, birth defects and other diseases.

In the laboratory, Roundup has been shown to inhibit steroidogenesis,⁶⁷ the production of steroid hormones. Both Roundup and glyphosate have been found to inhibit the aromatase enzyme involved in estrogen production, though Roundup was more potent.⁶⁸ Glyphosate formulations have also been shown to cause cell death and necrosis in various human cell cultures at fairly low levels.⁶⁹ Experiments by Argentine scientist Alejandra Paganelli and colleagues on frog and chicken embryos suggest that at sufficient doses, glyphosate formulations induce congenital craniofacial malformations.⁷⁰ Similar malformations were found in tadpoles exposed to glyphosate formulations.⁷¹ Glyphosate formulations are highly toxic to frogs, and their extremely heavy use may be one of several factors implicated in the global decline of amphibians.⁷²

For a comprehensive assessment of studies examining glyphosate's human and environmental toxicity, see PANAP's glyphosate monograph⁷³ and the 2012 update.⁷⁴

2.4.2 Other herbicide-resistant crop-associated herbicides

Just as Roundup Ready crops have driven a huge increase in glyphosate use, so the introduction and wider adoption of other HR crops will drive dramatic increases in the use of the herbicides associated with them. For instance, it is projected that 2,4-D corn and soya, if widely adopted, would increase the annual amount of 2,4-D used in American agriculture from 27 million lbs. (or 12,247 tonnes) (2007) to well over 100 million lbs (or 45,359 tonnes).⁷⁵ Very brief descriptions of some of the toxic effects of these herbicides are presented below.

Like similar organochlorine pesticides, 2,4-dichlorophenoxyacetic acid (2,4-D) is associated with various serious illnesses, including cancer, reproductive system disorders and neurological disease. Numerous epidemiological studies link exposure to 2,4-D and other herbicides of its class to the deadly immune system cancer non-Hodgkin's lymphoma.⁷⁶

This link is regarded as "the strongest association" found in epidemiological investigations of pesticides.⁷⁷ Other studies report a higher incidence of birth malformations in wheat-growing counties of Minnesota and neighboring states where 2,4-D is heavily used.⁷⁸ Depressed sperm counts have been found in 2,4-D-exposed men,⁷⁹ and recent epidemiology suggests a link between 2,4-D and Parkinson's Disease,⁸⁰ among other adverse health effects attributable to this herbicide.⁸¹ It is generally thought that 2,4-D's toxicity is attributable to dioxin contaminants generated in its production. Dioxins are extremely potent and persistent carcinogens and endocrine disruptors that bioaccumulate up the food chain. According to the EPA, 2,4-D is the seventh largest source of dioxins in the U.S.⁸²

Dicamba exposure has been linked to increased rates of non-Hodgkin's lymphoma as well as colon and lung cancer in farmers by U.S. NIH scientists.⁸³ There is also evidence that dicamba inhibits a critical nervous system enzyme (acetylcholinesterase).⁸⁴ Pregnant mice dosed with a commercially available mixture of dicamba, 2,4-D and mecoprop had smaller litters, suggesting developmental toxicity.⁸⁵

Imazethapyr, one of the most widely used imidazolinone herbicides, will be heavily used on BASF's GM soybeans, which are slated for introduction in South America. Imazethapyr has been strongly linked to higher rates of colon and especially bladder cancer in pesticide applicators.⁸⁶ The latter findings are

strengthened by a century-long history of research that attributes bladder cancer to aromatic amines, the class of chemicals to which imidazolinones belong.⁸⁷

Glufosinate, increasingly used on GM LibertyLink crops, is a neurological and developmental toxin.⁸⁸ Glufosinate is scheduled to be phased out in European Union member countries in 2017 on the basis of its reproductive toxicity.⁸⁹

Isoxaflutole would be heavily used if Bayer's GM soybeans are introduced. According to the U.S. Environmental Protection Agency, isoxaflutole demonstrates developmental toxicity and is also a probable human carcinogen. Isoxaflutole is persistent and mobile, and may leach and accumulate in groundwater and through surface water.⁹⁰



2.5 Agronomic Harms of Herbicide-Resistant Crops

2.5.1 Plant and soil health

Glyphosate resistance makes it possible for the first time to apply high rates of glyphosate formulations directly to crops. A growing body of research suggests that continual use of this chemical may seriously disrupt soil microbial communities, and make glyphosate-resistant plants more susceptible to disease, deficient in key nutrients, and lower yielding than conventional crops, among other adverse impacts.

“2,4-D is associated with various illnesses, including cancer, reproductive system disorders and neurological disease. Dicamba exposure has been linked to increased rates of non-Hodgkin’s lymphoma as well as colon and lung cancer.”

When glyphosate is sprayed on a Roundup Ready crop, much of the herbicide ends up on the surface of the soil, where it is degraded by microorganisms. However, some is absorbed by the plant and distributed to growing tissues and roots. Small amounts of glyphosate are released from the roots and spread throughout the surrounding soil.⁹¹ This rhizosphere is home to diverse soil organisms, such as bacteria and fungi, that play critical roles in plant nutrition and health.

Once in the rhizosphere, glyphosate can have several effects. First, it promotes the growth of certain plant disease organisms, such as *Fusarium* fungi, on the roots of Roundup Ready (RR) plants.⁹² Glyphosate treatment increases the severity of sudden death syndrome (SDS), a serious plant disease caused by *Fusarium*, in Roundup Ready soybeans.⁹³ The frequency and severity of SDS rise with the ever higher glyphosate rates farmers are using to control glyphosate-resistant weeds.⁹⁴ Even non-RR crops planted in fields previously treated with glyphosate are more likely to be damaged by fungal diseases such as *Fusarium* head blight, as has been demonstrated with wheat and barley in Canada.⁹⁵ This research suggests that glyphosate has long-term effects that persist even after its use has been discontinued. Second, glyphosate can alter the community of soil microorganisms, interfering with the plant's absorption of important nutrients. For instance, glyphosate's toxicity to root-associated rhizobia bacteria can decrease the absorption of nitrogen by RR soybeans under conditions of water deficiency, and thereby reduce yield.⁹⁶ Glyphosate also suppresses manganese-reducing microorganisms in the rhizosphere of RR soybeans.⁹⁷ Glyphosate treatment of glyphosate-resistant sunflower reduces the uptake and transport of both manganese and iron.⁹⁸

Glyphosate is known to chelate (bind to) minerals such as manganese,⁹⁹ and thus may bind minerals inside RR crop tissues and make them unavailable to the plant. Studies simulating low level glyphosate spray drift to non-transgenic soybean cultivars have demonstrated reduced leaf concentrations of calcium, manganese and magnesium as well as reduced soybean seed concentrations of calcium, magnesium, iron and manganese.¹⁰⁰ In short, glyphosate treatment can increase disease susceptibility by fostering the growth of disease microorganisms, suppressing beneficial microbes, inhibiting the production of plant defense compounds, and reducing uptake of minerals essential to plant health and disease resistance.¹⁰¹

2.5.2 Herbicide drift, crop damage and “defensive adoption”

Herbicides often drift beyond the field of application, and under the right conditions can drift far enough at sufficient concentrations to affect people's health and damage neighboring crops. Windy conditions, small droplet size, and hot weather are conditions that foster drift. This risk of “drift damage” is much increased with HR crops, because herbicide use occurs later in the season when neighbors' crops have leaved out and are thus more susceptible to drift injury.

In the U.S., surveys by state pesticide officials show that glyphosate has been the second-leading cause of drift-related crop injury in the Roundup Ready era.¹⁰² For instance, tomato growers in Indiana and neighboring states have reported over one million dollars' worth of crop damage over a four-year period from glyphosate drift.¹⁰³ Because glyphosate kills such a broad range of plants, virtually all crops are at risk of drift injury, unless they are also glyphosate-resistant.

Some farmers have felt compelled to grow Roundup Ready varieties to protect their crops from drift injury, even if they would otherwise prefer to grow cheaper conventional varieties. For instance, many farmers in Arkansas first grew Roundup Ready corn for this “defensive” purpose.¹⁰⁴ Given the similarity of farming practices across the U.S., it is highly likely that farmers in other states have done the same. As a result, farmers pay more for expensive RR seed they would prefer not to grow.

k Herbicides are normally applied prior to planting or before the seed sprouts with conventional crops in order to avoid damaging the crop.

Eventually, many then become locked into the RR system, spraying glyphosate as their neighbors do. In this scenario, only Monsanto profits, from increased sales of RR seeds and Roundup. Of course, growers of vegetables and other non-Roundup Ready crops remain highly susceptible to severe injury from glyphosate drift.

2,4-D and dicamba are both highly drift-prone. Despite being used much less than glyphosate, these herbicides ranked first and third, respectively, as culprits in drift-related injury episodes in the surveys mentioned above.¹⁰⁵

Both herbicides are toxic at low levels of drift to most broadleaf crops, a category that includes vegetables, fruit trees, and practically any non-cereal crop. Grapes and cotton are particularly sensitive. In the first several decades of 2,4-D use in Iowa, vineyard growers complained repeatedly about crop damage from 2,4-D drift, and called in vain for a statewide ban on the herbicide.¹⁰⁶ Vineyards continue to be damaged by the herbicide today.¹⁰⁷

In a recent episode that involved the spraying 2,4-D on 1,000 acres of pasture in California, drift damage to cotton was recorded at up to 100 miles away. A 50-acre pomegranate orchard was also severely damaged.¹⁰⁸ Such episodes will become much more frequent with the huge increase in 2,4-D use that will accompany the introduction of 2,4-D-resistant crops.

Some farmers in the U.S., namely, growers of vegetables, grapes and trees, are so concerned about the risks to their livelihood that they have formed the Save Our Crops Coalition to oppose the approval of 2,4-D and dicamba-resistant crops.¹⁰⁹

Most of the world's HR crops are grown as vast monocultures of soybeans and corn in North and South America. HR crop-related drift makes it still more difficult for growers of vegetables, fruits and other smaller-acreage crops to survive in such landscapes, decreasing what little crop diversity remains.

Increasing drift from ever more HR crops is thus not only a health threat; it could also seriously threaten the ability of small farmers to feed their families. Developing nations should carefully consider these consequences as they decide whether to allow these crops to be grown in their countries.



Tillage, the preparation of land for growing crops, can build up high levels of organic matter in the soil when used in organic farming systems.

3.0 BIOTECHNOLOGY = PATENTED SEEDS + PESTICIDES

3.1 Industry's Motivations

The agricultural biotechnology industry's single-minded focus on HR crops becomes more understandable when one considers its history and profit motivations. This industry represents an historic merger of two distinct sectors: agrochemicals and seeds. Beginning in the 1980s, the world's largest pesticide-makers—companies like Monsanto, Syngenta, Bayer, Dow and DuPont—began buying up the world's seed firms. These five biotech giants now control an astounding 58% of the world's commercial seed supply; together with BASF, they account for 67% of combined seed + agrochemical sales (see table below). These pesticide-makers understood that the new technology of genetic engineering would enable them to develop herbicide-resistant crops to exploit profitable "synergies" between their old pesticide and new seed divisions.

Herbicides are big business. In 2007, the world's farmers spent \$15.5 billion dollars to apply over 2 billion lbs (or 907,185 tonnes) of these chemicals. Herbicides represent 40% of the world's pesticide use, more than twice as much as insecticides (17%), and an equivalent percentage of pesticide sales (39%).¹¹⁰ In the short term, HR crops dramatically increase sales of the associated herbicides. In the longer term, weeds evolve resistance, generating demand for new HR crops and additional herbicides. In a sense, HR crops are the agricultural equivalent of the automobile industry's "planned obsolescence" strategy, only the weed resistance they generate has much more serious repercussions: the public health and environmental harm resulting from greater toxic pesticide use.

Table 1. The top six companies in agrichemicals and seeds

Top Six Companies in Agrichemicals and Seeds (2009 Sales, in billions of dollars)							
Rank	Company	Seeds +		Seeds		Agrichemicals	
		Sales	Market Share	Sales	Market Share	Sales	Market Share
1	Monsanto (USA)	11.724	16%	7.297	27%	4.427	10%
2	Syngenta (Switzerland)	11.055	15%	2.564	9%	8.491	19%
3	Bayer (Germany)	8.224	12%	0.7000	3%	7.544	17%
4	DuPont (USA)	7.044	10%	4.641	17%	2.403	5%
5	BASF (Germany)	5.007	7%	NR	NR	5.007	11%
6	DOW (USA)	4.537	6%	0.635	2%	3.902	9%
Top 6 company		47.611	67%	15.837	58%	31.774	71%
Total market		71.400		27.400		44.400	

Source: "Who Will Control the Green Economy," ETC Group, November 2011, pp. 22, 25.

After telling farmers for so many years that they could plant Roundup Ready crops every year without risk of weed resistance¹¹¹ Monsanto is now set to capitalize on the glyphosate-resistant weed epidemic fostered by its bad advice. The company's dicamba-resistant soybeans, corn and cotton will be targeted to growers with glyphosate-resistant weeds.¹¹² It is interesting to note that Monsanto's planned 2014 introduction of patented dicamba-resistant crops also coincides with the expiration of its first patents on a Roundup Ready crop (soybeans) in 2014.¹¹³

Monsanto is not alone. Dow is explicitly marketing its 2,4-D crops and proprietary brand of 2,4-D to farmers with glyphosate-resistant weeds as the "Enlist Weed Control System." Dow officer, John Jachetta, celebrates the market opportunity created by glyphosate-resistant weeds as inaugurating a "new era" of "very significant opportunities" for chemical companies. Syngenta likewise sees the herbicide business as becoming "fun" once more.¹¹⁴

3.2 Lawsuits against Farmers and the Demise of Seed-Saving



Aerial spraying of pesticides on a corn field. Pesticide drift is an insidious threat to human health, wildlife and ecosystems

The agrochemical giants' spending spree to acquire seed firms was also stimulated by a series of U.S. Patent Office and court decisions in the 1980s that established the right of firms to patent living organisms: first, a GE bacterium, and soon after plants. Biotechnology firms, especially Monsanto, have exploited their patents on GE seeds to outlaw seed-saving, forcing farmers to return to the market each year to buy new (patented) GE seeds.

Patents are generally issued on genes inserted into GE crops, methods to introduce them, and the GE crops themselves. The gene patents are particularly valuable, as the same gene (e.g. that conferring glyphosate-resistance) can be deployed in multiple crop varieties, and exploited to assert patent rights to them.

Biotechnology firms force farmers to sign "technology use agreements" as a condition of seed sales. These contracts stipulate that a farmer who re-plants second-generation (saved) seed is subject to prosecution for patent infringement.

¹¹ At least six cases involved forged signatures, a common practice among seed dealers. CFS (2005), op. cit., pp. 43-44.

As detailed in The Center for Food Safety's (CFS's) 2005 report, *Monsanto vs. U.S. Farmers*,¹¹⁵ Monsanto maintains a department with 75 employees and an annual budget of \$10 million to investigate and sue farmers suspected of such seed-saving. Nearly all cases have involved Roundup Ready soybeans. The company hires private investigators to investigate roughly 500 farmers each year. According to farmers interviewed by CFS, these investigators trespass on their property to take photos or crop samples, issue threats, adopt disguises (e.g. pretend to be conducting surveys of seed and chemical purchases), and even engage in activity that closely resembles entrapment.

Farmers have been convicted of patent infringement even when they purchased seed without having been presented with or having signed any technology use agreement. In other cases, Monsanto has sued farmers based on contamination of their conventional crops (via cross-pollination or seed dispersal) with the company's patented variety or detection of Roundup Ready 'volunteer' seed in an otherwise conventional field. Neither situation involves intentional infringement of Monsanto's patent rights. In one case, Monsanto mistakenly filed a federal lawsuit against a store-owner who had never farmed at all.¹¹⁶ Monsanto also has a 'snitch line' by which farmers can anonymously report a neighbor suspected of saving Monsanto's seeds. One judge referred scathingly to Monsanto's "scorched earth policies" in pursuing farmers, noting that they have bred an atmosphere of distrust and suspicion in rural communities.¹¹⁷

CFS has tracked Monsanto's investigations and prosecution of U.S. farmers. As of December 2012, public court records reveal 142 lawsuits involving 410 farmers and 56 farm businesses. Of those 72 lawsuits that ended with recorded damages, sums awarded to Monsanto totaled \$23,675,821.¹¹⁸ These numbers, however, do not begin to tell the whole story. As one district court judge noted: "the vast majority of cases filed by Monsanto against farmers have been settled before any extensive litigation took place."¹¹⁹ Based on materials downloaded from Monsanto's website in 2006, CFS has arrived at a rough estimate of the scope of out-of-court settlements that are not captured in the figures cited above. Based on Monsanto's data, the company has collected between \$85.6 to \$160.6 million dollars from farmers in 2,391 to 4,531 cases involving what the company terms "seed piracy matters."¹²⁰

CFS has spoken with many farmers pursued by Monsanto via a hotline set up with the publication of its 2005 report. Even those farmers who did not save seed were very likely to settle with the company. This willingness to accede to an unjust settlement arises from an understandably intense fear of facing this multinational giant in court, which can easily cost hundreds of thousands of dollars in legal fees. Even when victory is likely, just a small chance of defeat is intolerable, for in some cases that defeat would entail the loss of the farmer's farm and the only life he or she has ever known.

3.3 Rising GM Seed Prices, Few Alternatives

In the U.S., the proportion of cropland grown from saved seed was quite high as recently as 1982: 45% of soybeans and 50% of cotton.¹²¹ One reason farmers save seed is to save money. The legal right to save seed also restrains seed firms from pushing through excessive price hikes.¹²²

With over 90% of U.S. soybeans and cotton planted to patented GE varieties today,¹²³ seed-saving has plummeted. The elimination of this low-cost option has allowed seed firms to dramatically raise seed prices. USDA data show that the average cost of soybean seed to plant one acre increased by 60% over the two decades prior to the 1996 introduction of Roundup Ready soybeans (1975-1995): from \$8.32 to \$13.32 per acre. In the 16 years since (1995-2011), per acre seed costs have risen by a dramatic 325%, from \$13.32 to \$56.58. Similar trends are evident for corn and cotton seeds.¹²⁴

Farmers who would prefer to grow cheaper, unpatented conventional seeds that they can legally save have very few high-quality options today, thanks to the agrochemical giants' stranglehold on the seed supply.¹²⁵ In fact, there is great demand for conventional soybeans in several states. But the supply is not

is not sufficient to meet this demand.¹²⁶ Reasons that farmers cite for preferring conventional seed are low cost, the excessive price of Roundup Ready varieties, and the legal right to save seeds for replanting.¹²⁷

Farm-saved seed represents 80-90% of all seed used in many developing countries.¹²⁸ Losing the legal right to save seeds, and instead being forced to purchase expensive patented seeds, would be disastrous for many poor farmers. Developing nations should carefully consider the U.S. experience before inviting Monsanto and other multinational seed giants into their countries.

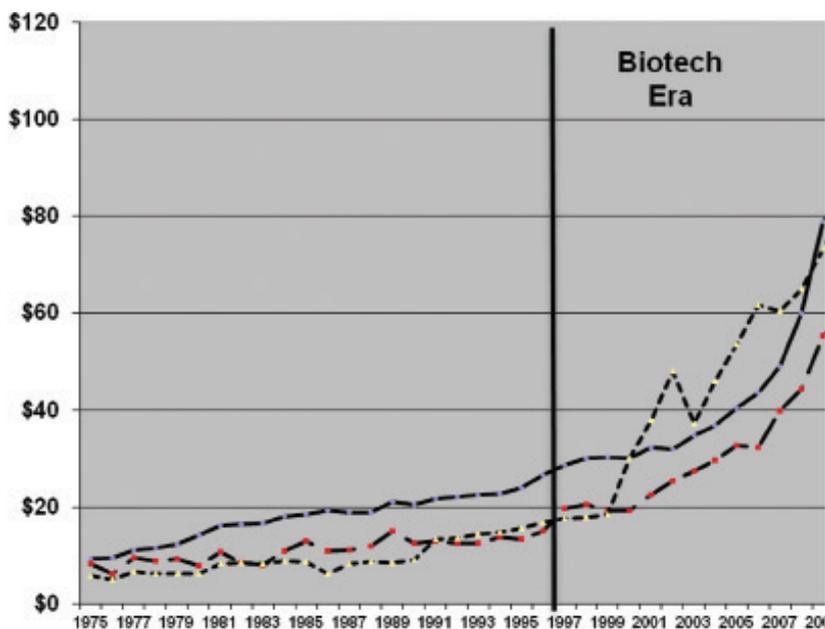


Figure 2. Average cost of corn, soybean and cotton seed in the U.S. from 1975 to 2011 (USD per planted acre)

Source: USDA Economic Research Service: Commodity Costs and Returns: U.S. and Regional Cost and Return Data. 1975-2011 datasets accessible at: <http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm>.

4.0 DEBUNKING THE MYTHS ABOUT HERBICIDE-RESISTANT

4.1 Herbicide-Resistant Crops Do Not Lead to the Adoption of Conservation Tillage Practices or Combat Global Warming

Contrary to conventional wisdom, Roundup Ready crops have not driven greater use of conservation tillage, defined as tillage practices that leave crop residue on the soil. Nor are they responsible for benefits commonly associated (rightly or wrongly) with conservation tillage, such as lesser soil erosion and reduced global warming gas emissions.¹²⁹

The big gains in U.S. acreage under conservation tillage occurred from the 1970s to the mid-1990s, prior to the 1996 introduction of RR crops. Most of these gains were spurred by strong financial incentives to adopt soil-conserving farming practices contained in the 1985 and subsequent Farm Bills. The success of these policies is reflected in dramatically declining soil erosion over this period.

In fact, both the adoption of conservation tillage practices and soil erosion rates have leveled off in the Roundup Ready crop era. And ironically, the epidemic of GR weeds fostered by RR crop systems has actually increased the use of soil-eroding tillage in at least four states, as discussed earlier. Since new HR crops will foster still more intractable weed resistance, their ultimate effect will be to further increase soil erosion via greater use of tillage for weed control.

4.2 Yield Drag, Not Gain, with Roundup Ready Crops

Contrary to loose claims by biotech industry-funded groups, no commercial GE crops have been engineered for increased yield potential. In fact, Roundup Ready soybeans have been found to suffer from a “yield drag” compared to conventional lines.¹³⁰ A recent independent assessment of GM crop performance (compared to their closest conventional relatives) confirms that conventional breeding, not biotechnology, is the engine of continuing yield increases in modern corn and soybean varieties.¹³¹

As noted on the previous page, one of Argentina’s largest soybean growers, Gustavo Grobocopatel, also found that Roundup Ready soybeans yielded less than conventional varieties. To the very limited extent that yield performance in industrial monoculture crops has anything to do with world hunger, herbicide-resistant crops must be declared a dismal failure. Proponents of GM crops have yet to explain why the 160 million hectares of GM crops being grown today have failed to put a dent in world hunger, which has increased from less than 800 million hungry people in the mid-1990s, when GE crops were first introduced, to over 900 million in 2010.¹³²

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4.3 Alternative Weed Control Practices

The agrochemical-seed industry would have us believe that intensive herbicide use with HR crops is the only way to control yield-robbing weeds. This is certainly not the case. For one, intensive herbicide use is designed to eradicate weeds. More sophisticated approaches developed by farmers and agronomists seek instead to manage weeds, suppressing them sufficiently to avoid yield loss. For instance, numerous studies have shown that organically grown crops yield as well as their herbicide-treated counterparts, despite having much higher weed infestation levels.¹³³ Such approaches recognize that weeds can even benefit crops: by providing ground cover that inhibits soil erosion and the attendant loss of soil nutrients, habitats for beneficial organisms such as ground beetles that consume weed seeds, and organic matter that when returned to the soil increases fertility and soil tilth.¹³⁴

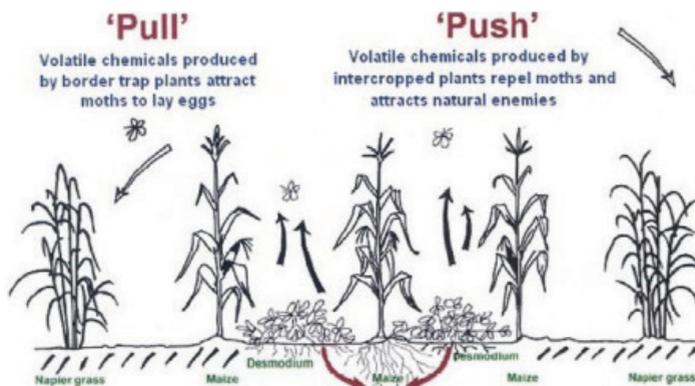
m In fact, pesticide industry representatives are already propagandizing for the greater use of herbicides and HR crops in Africa. See Gianessi, L. (2009). “Solving Africa’s weed problem: increasing crop production & improving the lives of women.” CropLife Foundation, December 2009. CropLife Foundation is the main pesticide industry lobby group.
n “No-Till Revolution,” Rodale Institute, http://www.rodaleinstitute.org/no-till_revolution.

Non-chemical weed management techniques—some of which are not utilized specifically or primarily for weed control—include crop rotation, the planting of cover crops, intercropping, mechanical methods, advanced fertilization techniques and higher plant density.¹³⁵ Utilized in combination, as part of an integrated weed management (IWM) approach, these techniques are extremely effective at preventing yield loss from weeds.¹³⁶

Cover crops are plants other than the main cash crop that are seeded after the main crop is harvested and killed before the new crop is sown. Herbicides are sometimes used to kill the cover crop in herbicide-resistant or conventional crop systems. But mowing or rolling the cover crop is superior. Mechanical crop rollers for cover crops and annual crops like grains have been used successfully for decades in Brazil, Argentina and Paraguay.¹³⁷ New versions are being developed by organizations such as the Rodale Institute in the U.S., making organic no-till a viable option. These machines roll and crimp the vegetation, killing it and leaving a thick mat of slowly decomposing material that suppresses weeds, conserves moisture, and sequesters carbon in the soil. Seeds are then drilled or seedlings directly planted through the mat.¹³⁸

Intercropping—seeding an additional crop amidst the main crop—suppresses weeds by acting as a living mulch that competes with and crowds out weeds.¹³⁹ Some cover and intercrops exude weed-suppressive chemicals into the soil, providing further benefits. Planting crops more densely leads to more rapid closure of the crop “canopy,” which shades out and so inhibits the growth of weeds. Fertilization practices that favor crops over weeds include the injection of manure below the soil surface rather than broadcast applications over the surface.

In east Africa, intercropping has been used with spectacular success in the ‘push-pull system’ for corn cultivation to suppress the extremely damaging *Striga* or witchweed.¹⁴⁰ The push-pull system—which is now utilized on 15,000 hectares in Kenya, Uganda and Tanzania by over 30,000 small farmers—also provides natural control of the most serious corn pest, the corn stem borer¹⁴¹ (the image below illustrates how the system works).



Source: “Planting for Prosperity – Push-Pull: A model for Africa’s green revolution,” The International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya, 2011.

Chemicals secreted by desmodium roots control *Striga* and deplete *Striga* seed bank in the soil
Desmodium roots fix atmospheric nitrogen in the soil; shoot and root biomass increase soil organic matter

Desmodium roots fix atmospheric nitrogen in the soil; shoot and root biomass increase soil organic matter

Appropriate technology can also be utilized to make weeding much less arduous. Simple wheel hoes—widely used in organic farming systems in the U.S.—have a weed-uprooting blade mounted behind a single wheel.¹⁴² Handles allow the wheel hoe to be pushed along easily, from an upright posture, to rapidly uproot small weeds. Simple tools of this sort would seem to have great potential to increase the efficiency and productivity of smallholder farmers in developing countries.

These non-chemical weed control systems are effective, inexpensive, and free of the many downsides of intensive herbicide use associated with herbicide-resistant crops: high cost, weed resistance, crop injury from herbicide drift, and the plethora of human health and environmental harm associated with herbicides.

5.0 CONCLUSION

The biotechnology industry has long maintained that GM crops are essential to feed a growing population. Yet what they have in fact delivered is a pesticide-promoting technology, herbicide-resistant crops that have nothing to do with hungry people or poor farmers. Herbicide-resistant crops are designed to save labor in large, industrial farming operations. The experience of North and South America shows that these crops have increased the use of toxic herbicides, fostered the epidemic spread of resistant weeds, and damaged neighboring crops via frequent drift episodes. Most insidiously, they have facilitated expanding monocultures that have displaced small farmers growing food to feed their families.

Herbicide-resistant crops are a natural choice for the agrochemical firms that have bought up much of the world's seed supply, as they provide double profits from both expensive HR seeds and the herbicides used with them. Further profits come from patents on the seeds, which enable the biotech giants to outlaw seed-saving and force farmers to buy commercial seed every year. Monsanto has sued thousands of U.S. farmers, who have paid the company tens of millions of dollars in lawsuits alleging "patent infringement" for seed-saving. Losing the legal right to save seed would be catastrophic for small farmers in many developing countries.

HR crops facilitate weed eradication via the intensive use of herbicides. More sophisticated approaches use multiple non-chemical techniques to manage weeds. Such integrated weed management is cheaper, more sustainable, and free of the many harms ensuing from the chemical-intensive approach.

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- 5 Stone, GD (2012). "Bt cotton, remarkable success, and four ugly facts," *Food, Farming and Biotechnology*, a blog by anthropologist Glenn Davis Stone, who has conducted over a decade of research on adoption of Bt cotton in India. <http://fieldquestions.com/2012/02/12/bt-cotton-remarkable-success-and-four-ugly-facts>.

- 6 The Roundup Ready gene was derived from a strain of *Agrobacterium* that had evolved resistance to glyphosate in waste ponds outside of Monsanto's Louisiana glyphosate manufacturing plant. See Charles, D. (2001). *Lords of the Harvest: Biotech, Big Money, and the Future of Food*, pp. 68-69.
- 7 ISAAA (2011), op. cit. See section entitled "Adoption by trait – herbicide tolerance remains the dominant trait." Total herbicide-resistant (HR) crop acreage is the sum of HR crops and "stacked" crops with both HR and insect-resistance traits.
- 8 Monsanto (2012). "First Quarter 2012 Financial Results," Monsanto Company, 1/5/12, p. 9.
- 9 Roughly 1 million acres of LibertyLink corn, cotton and canola were planted in 2006, see: Freese, B. (2007). "Cotton Concentration Report: An Assessment of Monsanto's Proposed Acquisition of Delta and Pine Land," International Center for Technology Assessment/Center for Food Safety, February 2007, p. 34. The recently introduced LibertyLink soybeans were planted on 1.3% of US soybean acreage (978 million acres) in 2011. See: USDA APHIS (2012). "Dow AgroSciences Petition (09-349-01p) for Determination of Nonregulated Status of Event DAS-68416-4," Draft Environmental Assessment, USDA APHIS, p. 28.
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Pesticide Action Network Asia and the Pacific (PAN AP) is one of five regional centres of PAN, a global network which aims to eliminate the harm caused by pesticides and promote biodiversity-based ecological agriculture. It is committed to the empowerment of people especially women, agricultural workers, peasants and indigenous farmers. PAN AP launched its Save Our Rice Campaign in 2003 in response to the powerful threats arising against rice, the staple food of half the world's population.

The foundation of the Campaign is the "Five Pillars of Rice Wisdom": (1) Rice Culture, (2) Community Wisdom, (3) Biodiversity-based Ecological Agriculture, (4) Safe Food and (5) Food Sovereignty. The Campaign is dedicated to saving traditional local rice, small rice farmers, rice lands and the rice heritage of Asia. PAN AP Rice Sheets provide relevant information on the threats to rice and are written from the people's perspective. Enquiries may be sent to: panap@panap.net

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