Report 4

Are GM crops better for farmers?

Canadian Biotechnology Action Network

GMO Inquiry 2015

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Collaborative Campaigning for Food Sovereignty and Environmental Justice

The GMO Inquiry 2015 is a project of the Canadian Biotechnology Action Network (CBAN). CBAN is a campaign coalition of 17 organizations that researches, monitors and raises awareness about issues relating to genetic engineering in food and farming. CBAN members include farmer associations, environmental and social justice organizations, and regional coalitions of grassroots groups. CBAN is a project on the shared platform of Tides Canada.

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GM = genetically modified (also called genetically engineered) **Ht** = herbicide-tolerant
HR = herbicide-resistant **Gt** = glyphosate-tolerant
GR = glyphosate-resistant

SUMMARY

This fourth report of *GMO Inquiry 2015* investigates the impacts and risks of genetically modified (GM; also called genetically engineered or GE) crops on farms and famers over the past twenty years, with a focus on Canada.

The use of patented GM traits has helped facilitate corporate consolidation in the seed market. **Markets for GM crops are dominated by a few seed and agrochemical companies**. This high level of corporate concentration in the seed market has meant higher prices, limited choices for farmers, a narrowing of genetic diversity in crops, and stagnating innovation. Legal control over seeds has also increased, in the form of patents on genetic sequences and other mechanisms that prevent farmers from saving, exchanging and reusing seed. GM crops have diminished the choices available to farmers, while strengthening the control of a few companies.

Yields in GM and non-GM crops have increased at a similar rate in Canada, and **there are no clear patterns to show that GM crop yields have increased more than those of non-GM crops**. In fact, research comparing GM crops in North America and non-GM varieties of the same crops grown in Europe has shown that non-GM crop yields have increased as much, or more. GM traits are added to plant varieties that are already high-yielding due to background genetics developed through non-GM breeding methods. It is these pre-existing characteristics, along with other factors, that have determined yield increases in the past decades, not GM traits.

Growing GM crops is not putting more money into the pockets of Canadian farmers. **Although gross farm income in Canada has increased over the past two decades, realized net income (the income remaining after farm expenses are paid) has not changed significantly**. Farm expenses have increased substantially, in part because of the rising prices of seeds and other inputs. GM crops have fed into this pattern; GM seeds are significantly more expensive than non-GM seed, in Canada and other countries.

The major benefit that GM herbicide-tolerant crops offered farmers was simplified weed management. However, **the increased use of herbicides has led to the emergence and spread of herbicide-resistant weeds**, which are reversing this benefit and creating new costs and complications for farmers. The biotechnology industry's solution to this problem is to sell new GM crops that are tolerant to different herbicides, an approach that will further drive up herbicide use and speed up the spread of herbicide-resistant weeds.

GM contamination can also present serious costs for farmers. The examples of GM flax contamination, which closed Canada's export markets, and GM canola contamination, which meant that most Canadian organic farmers were forced to stop growing canola, stand testament to these costs. Despite these experiences, new GM crops such as the GM alfalfa are being commercialized. If released in Canada, GM alfalfa contamination will have serious and irreversible impacts, the brunt of which will be borne by organic and other non-GM farmers.

The Canadian government does not assess the agronomic and economic impacts of GM crops or evaluate the benefits or risks they pose, and farmers are not consulted before GM crops are approved for growing. The experiences of the past twenty years show us that there is an urgent need for a democratic decision-making process to assess what role, if any, GM crops should play in our food and farming systems.

GMO INQUIRY 2015

Twenty years ago, in 1995, the Canadian government approved the first genetically modified (GM, also called genetically engineered or GE) canola varieties, as well as the first GM soy, GM tomatoes (not currently on the market) and GM potatoes (not currently on the market). With these decisions, the government introduced genetically modified crops into our environment and food system for the first time.

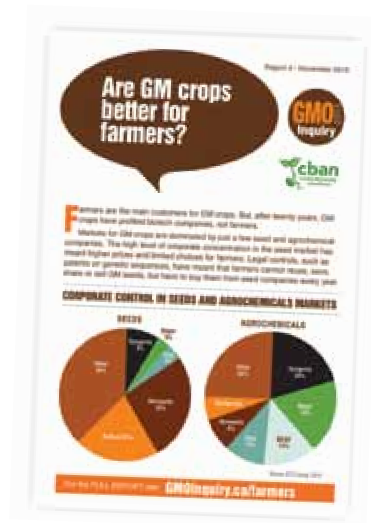
After 20 years, we still have major unanswered questions and hear conflicting messages about the impacts and risks of GM crops and foods. Even while our questions persist, the Canadian government has just approved the first-ever GM apple (this will be the first GM fruit grown in Canada) and could soon approve the first GM food animal (a GM salmon).

Canadian farmers and eaters want to know the impacts of GM crops – on our environment, our food and farming systems, our economy, and on our health. We want to know about the food we're growing, eating and buying. And we want to know who truly benefits from GM crops and foods, and who pays their costs and bears the burden of their risks.

The Canadian government has not monitored or shared detailed information to answer these questions. However, research in Canada and from around the world, as well as the experiences of farmers in Canada and other countries, helps shed light on the problems with GM over the past two decades. It's time to bring our research together and assess the evidence, so that we can decide whether GM crops have a place in the future of our food system.

This is the fourth of a series of reports that are part of **GMO Inquiry 2015**. All reports are posted at **www.gmoinquiry.ca**.

- Where in the world are GM crops and foods? www.gmoinquiry.ca/where
- Are GM crops better for the environment? www.gmoinquiry.ca/environment
- Are GM foods better for consumers? www.gmoinquiry.ca/consumers
- Are GM crops better for farmers? www.gmoinquiry.ca/farmers
- Are GM crops and foods well regulated? *Coming soon*
- Do we need GM crops to feed the world? *Coming soon*



Read and print the summary pamphlet for this report at GMOinquiry.ca/farmers

INTRODUCTION

Farmers are the main customers for GM crops. However, after twenty years, have GM crops benefitted farmers, and what risks do they pose?

So far, four crops – corn, canola, soy and cotton – dominate global acres of GM crops. These crops are genetically modified with one or both of just two GM traits – herbicide tolerance and insect resistance. These traits came with promises to simplify weed management, reduce pesticide use and reduce crop losses to weeds and insects. However, the emergence and spread of herbicide-resistant weeds is reversing the primary benefit of convenience and cost-savings in weed management. A previous *GMO Inquiry* report found that GM crops have increased, rather than decreased herbicide use over the past twenty years. In this report, we investigate their impact on yields and farmer incomes, and the costs of herbicide-resistant weeds and GM contamination.

GM crops are embedded in a system defined by tight legal and market control, and the concentration of farm inputs in the hands of a few large corporations. **After twenty years of GM crops, biotechnology companies are profiting from the use of GM traits, but this does not necessarily mean that farmers are also benefitting**.

It is critical that we understand the impacts of GM crops on Canadian farmers, in order to meaningfully assess what role they should play in the future of our food and agricultural systems, and whether equal or greater benefits can be achieved from non-GM approaches.

What is genetic modification?

Genetic modification (GM) is the introduction of new traits to an organism by making changes directly to its genetic makeup, e.g. DNA, through intervention at the molecular level. It's also called genetic engineering or GE. With genetic engineering, scientists can change the traits of plants and animals by inserting DNA pieces, whole genes, or long stretches of DNA segments from many different organisms. These sequences can also be taken from the same species or be newly made up. Scientists can also delete or swap DNA sequences in organisms or introduce genetic material to silence genes.

Unlike conventional breeding and hybridization, genetic engineering is a laboratory technology that enables the direct transfer of genes between organisms in different species or kingdoms that would not breed in nature, and the introduction of new sequences that do not even exist in nature.

GM CROPS AND CORPORATE CONTROL

The high level of corporate concentration in the seed market has meant higher prices, limited choices for farmers, a narrowing of genetic diversity in crops, and stagnating innovation. Along with market concentration, legal control over seeds has also increased, in the form of patents on genetic sequences and other mechanisms that prevent farmers from saving, exchanging and reusing seed. At the same time, there is almost no public breeding or farmer-supplied seed for the major crops that have GM varieties in Canada (corn, canola and soybean), and the seed market for those crops is dominated by a few multinational agrochemical corporations. For these crops, it can be difficult for farmers to even access non-GM seed.

GM SEEDS ARE NOT FARMER-OWNED SEEDS

One key difference between GM seeds and non-GM seeds is that the gene sequences inserted into GM seeds can be patented. These patents prevent farmers from re-using the seeds or sharing them with other farmers. Globally, these patents are owned by a few multinational seed and agrochemical companies. Farmers who use GM seeds purchase seeds from companies every year and sign contracts with numerous prohibitions and obligations. Companies profit from the sale of GM crops and royalties on GM traits and have almost no legal responsibilities towards the farmers who buy their seeds, or whose crops are contaminated by the patented gene sequences.

Most of the genetically modified seeds sown across the world are owned by just one company: Monsanto. In 2007, Monsanto owned approximately 85% of all GM crops planted around the world.[1] Monsanto has been the largest seed company in the world since 2005.

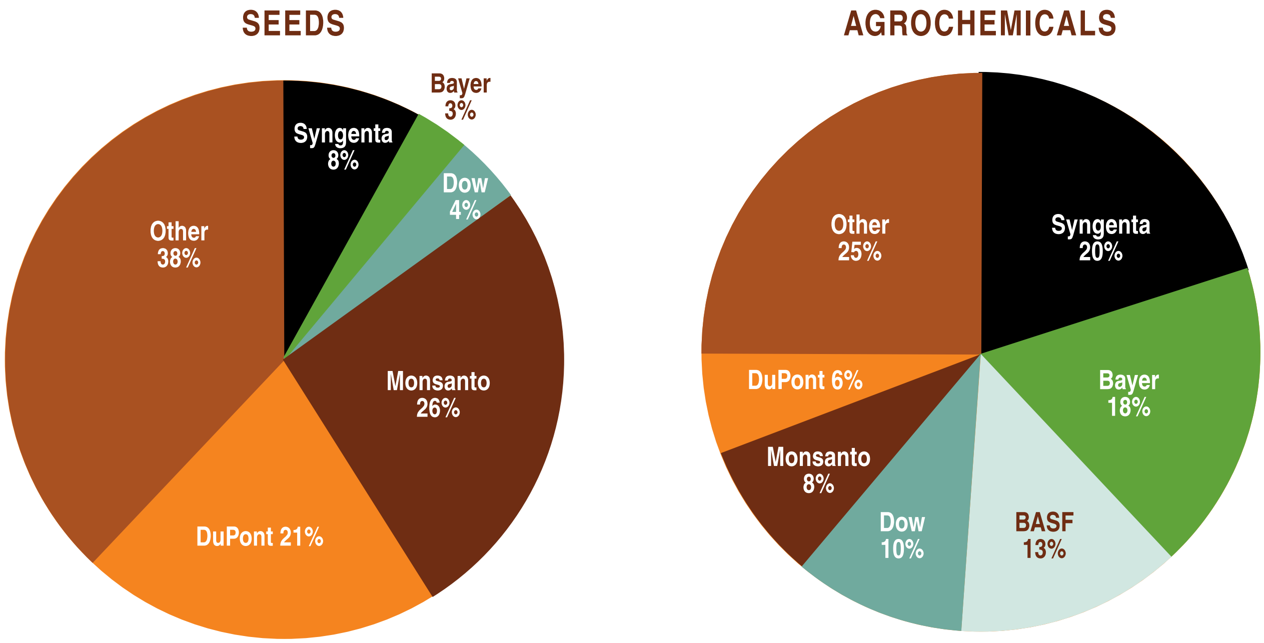
Monsanto is one of six companies that together control 63% of the global commercial seed market[2] (the top ten control 75%).[3] These same six companies also control 75% of the agrochemical market (pesticides, including herbicides, insecticides, and fungicides). All six develop GM seeds, and five of them sell GM seeds.

The “Big Six”

Six major companies are developing GM crops: Monsanto (US), DuPont (US), Syngenta (Switzerland), Dow (US), Bayer (Germany), and BASF (Germany). All of them, with the exception of BASF, also sell GM seed.

- Collectively, these six companies control 63% of the global commercial seed market and 75% of the agrochemical market.[4]
- Collective sales of these companies is over $65-billion a year in agrochemicals, seeds and GM traits.[5]
- The Big Six devote, on average, at least 70% of their seed and crop research and development to biotech and genetic engineering.[6]
- Since GM seeds were first introduced, the market share of the largest three of these companies has more than doubled, from 22% to 55%.[7,8]
- In 2007, these six companies accounted for 98% of global GM acres.[9]
- Approximately 85% of this global GM area was cultivated with GM traits from Monsanto.[10]

Figure 1: The Big Six: global seed and agrochemical market share



BASF invests in seed R&D, but does not sell seeds

Source: ETC Group, 2015[11]

According to the US Department of Agriculture (USDA), structural changes in the private-sector seed biotechnology industry since the mid-1990s have been even greater than in other farm input industries, including synthetic pesticides, synthetic fertilizers, farm machinery and animal health, genetics and nutrition.[12]

The corporate consolidation that has taken place in the seed market over the past twenty years was driven, in part, by the interest in genetic engineering, and the potential profits offered by gene patents in particular. In the 1980s, for instance, Monsanto began to transform itself from a chemical company into a seed company. It did this by acquiring several other small and large seed companies, and investing a large amount of money into developing GM herbicide-tolerant crops that were paired with its glyphosate-based herbicide, Roundup. Other companies also invested in seed company mergers and acquisitions, to access patents and seed genetics. As researchers for the USDA say, "Technological innovation in the form of modern, DNA-level biotechnology and changes in intellectual property rules have enabled private-sector companies to capture more value from the new seeds they develop."[13]

Corporate concentration in seeds and agrochemicals is not yet complete. In 2015, for instance, Monsanto, the largest seed company in the world, made a $46.5-billion bid to buy Syngenta, the largest pesticide company in the world. This bid failed, but such possible mergers would further consolidate the seed and agrochemical sectors, strengthening the market power of a few large players over our food and farming systems. Economists and government studies agree that whenever four or fewer enterprises control 50% or more of sales, it can be described as a cartel, and competition and innovation are at risk.[14]

Market share is not the only indicator of the power and influence of large agribusiness corporations. As the research organization ETC Group points out, these corporations are not just competitors – they are also collaborators – in tightly concentrated markets.[15] In 2006, for example, Monsanto and Dow AgroSciences signed a global agreement to cross-license or share their patented traits with each other.[16] Most GM crops are now stacked with a number of GM traits, which are sometimes licensed from multiple companies.

Patents and Terminator technology

Our entire food system is built on the work of farmers who have selected, saved, exchanged, sold and reused seed for generations. The value of a seed is realized not just in one harvest, but in the seeds it produces for future crops and the material it provides for future breeding. This value, however, does not fit with a corporate business model. **As long as farmers are able to openly save and re-use seeds, and plant breeders can openly use seeds to produce new varieties, companies cannot capture value from them.**

Patent protection over new genetic sequences is one legal mechanism that takes ownership of seeds out of the hands of farmers. A patent is granted to an inventor to allow them to make a profit from their work by excluding others from making, using, importing and selling it for a set period of time, usually fifteen to twenty years. Although Canada does not permit the patenting of plants themselves, new genetic sequences in plants can be patented, and patent-holders can stipulate the conditions under which the patented genetic material can be used. In practice, this means that patents allow the company that has developed a GM trait to forbid farmers from saving and replanting seeds with that trait, and public breeders from further selecting or developing it.

Patents also mean that farmers can be found in violation of intellectual property rights if seeds or plants with patented gene sequences are found on their farms. Companies such as Monsanto monitor compliance by conducting "field checks" on farmers' fields, and encouraging farmers to report possible cases of patent infringement, or what Monsanto calls "seed piracy."[17] As farmers in Canada and the US have discovered, this can mean being taken to court. By 2013, Monsanto had more than 1,676 patents on seeds, plants and other agricultural applications,[18] and had filed at least 144 seed patent infringement lawsuits in the US, involving 410 farmers and 56 small businesses in 27 states.[19]

Companies have also developed "Terminator" technologies (Genetic Use Restriction Technologies) that could provide biological patent enforcement. Such GM technologies make seeds sterile after first harvest. Terminator technology was jointly developed by the US Department of Agriculture and seed company Delta & Pine Land (now owned by Monsanto). In response to global farmer protests, there is an international moratorium on field-testing and commercializing Terminator technology, at the UN Convention on Biological Diversity.[20] This moratorium is constantly under threat.[21]

Large seed companies with GM investments spend billions of dollars on patents and patent lawyers, and on policing farmers. This system of legal controls, along with possible biological controls, exists to turn seeds into commodities that corporations can profit from, and take seeds out of the hands of farmers.

CORPORATE CONCENTRATION REDUCES FARMER CHOICE

We often hear the argument that farmers around the world are growing GM crops because they are choosing to buy GM seeds, and that GM crops provide more choices for farmers. However, corporate concentration in the seed market has meant that **the introduction of GM seed is often followed by the removal of non-GM varieties, and a decline in the options available to farmers**.

In Canada, for example, 80% of the 120 registered varieties[a] of canola in 2000 were non-GM. **By 2007, only five varieties of non-GM canola were available.**[22] As non-GM varieties are phased out, and because GM traits are bred into conventional crops that already have the best performance characteristics, buying GM seed is often the only way that farmers can access modern, high-yielding varieties. Additionally, as companies de-register old varieties in Canada, farmers using and saving those varieties lose the ability to use them.

Similarly, a 2010 study in Illinois found that 40% of farmers said they did not have access to high-quality non-GM corn seed.[23] Non-GM soybean seed has also become harder to find in the US.[24] The smaller quantities that are still being bred have fewer distribution channels. In 2008, Jim Skiff, president of US Soy said, "We heard from other growers who said they couldn't get non-GMO seed… There is getting to be less seed available."[25] US farmers had 9,000 corn varieties available to them in 2005, of which 57% were GM, but by 2010, non-GM varieties had declined by two thirds.[26] By 2010, only 17% of corn varieties, 10% of soybean varieties, and 15% of cotton varieties in US seed catalogues were non-GM.

Farmers in other countries have been faced with similar limitations. After the introduction of GM cotton in South Africa, non-GM seed became progressively less available,[27] and in India (where Monsanto controls the cotton seed market),[28] most seed suppliers stock very little or no non-GM cotton seed.[29] In Europe, a study comparing Spain, where a small amount of GM corn varieties are grown, and other countries that do not grow any GM crops found that the varieties available to farmers in non-GM adopting countries increased or remained consistent, while in Spain they declined significantly.[30] Between 2003 and 2013, an average of 49% of varieties added to the Spanish market were GM, while all the varieties removed were non-GM.

A related consequence of consolidation is that the major corporations that control the global markets for seeds and agrochemicals now also largely determine the priorities and future direction of agricultural research. The big six companies account for 75% of all private sector agricultural research into seeds and chemicals.[31] Research from the US, for example, found that increased industry concentration reduces biotechnology research and development (R&D intensity).[32]

In 2010, the US Department of Justice decided to investigate concerns about potential anti-competitive behaviour in the seed biotechnology industry.[33] The investigation was looking into allegations that Monsanto was stifling competition, including through agreements that stipulated the company's herbicide formula Roundup be the only herbicide that farmers could apply to Monsanto's GM "Roundup Ready" herbicide-tolerant crops.[34] Monsanto's competitor DuPont argued that "Monsanto has abused its unlawfully-acquired monopoly power to block competition, thwart innovation and extract from farmers unjustified price increases of over 100 percent in recent years."[35] The investigation was dropped in 2012, after three years, with no reason given.[36]

a In Canada, new seed varieties in some crop types require variety registration before being placed on the market for sale. This system was designed to confirm the merit and performance of new varieties, to avoid misrepresentation to farmers and harm to the market. De-registered seeds have little market-value.

The demise of public breeding in Canada

> "If we, as a nation, withdraw our resources from plant breeding, then all new seeds will be owned and controlled by global agribusiness corporations. Ultimately, those who control the seeds control most of the food we eat. Do we want to grant that kind of power to Monsanto, Bayer and Dow Chemicals?
>
> — National Farmers Union[37]

For hundreds of years, our seed system has relied on farmers, gardeners and public plant breeders who develop, improve, select and save varieties of seeds that they exchange, sell and reuse. Most of the crop varieties that form the base of our food system were developed by farmers and by public institutions funded largely by the government, and considered public goods.[38]

As recently as in the early 1980s, the public sector in Canada was responsible for 95% of plant breeding, and 100% of breeding for cereal crops and oilseeds.[39] Over the past two decades, however, the Canadian government has dismantled much of the public plant breeding infrastructure in Canada, and shifted the responsibility for plant breeding to the private sector.[40]

Since 2005, the federal government has closed down or cut funding to a number of important public breeding institutions in Canada. Research stations that have been closed include the Delhi Research Station in Ontario,[41] the Herve J. Michaud Experimental Farm in New Brunswick,[42] the Kamloops research centre in BC,[43] and the Cereal Research Centre in Winnipeg Manitoba. In 2014, Mackenzie County in Alberta bought the Fort Vermilion experimental farm in order to keep it active and prevent it from closing.[44]

The Cereal Research Centre (CRC) in Winnipeg holds a particularly important place in Canada's agricultural history. Approximately 50% of wheat and oat acreage in Canada, representing a value of $2.5-billion, is seeded to varieties that were developed at the CRC.[45] Since its inception in 1925, the CRC has released 27 wheat, 22 oat, 2 barley, 17 flax, 14 field pea, 123 ornamental and 53 fruit tree varieties.[46] The centre was closed in 2014.

Public breeding is economically efficient. According to research by Richard Gray, an agricultural economist at the University of Saskatchewan, when the Canadian federal government invests $30-million a year in wheat breeding, it creates $600-million in value, in the form of better crops, income for wages, taxes, and additional research resources.[47] Another study by Gray and other researchers found that every dollar invested by farmers in public breeding generated $20.40 in benefits in wheat varieties, and $7.56 in barley varieties.[48]

Private breeding is much less efficient. As canola breeding programs shifted from the public to the private sector, and despite a huge influx of private funds in the 1980s and 90s, the rate of return for canola diminished, while it has steadily increased for crops being developed by Canadian public breeding programs.[49] For

Continued…

The demise of public breeding in Canada continued

example, a $25-million annual public investment in wheat generated a similar yield increase to an $80-million private investment in canola breeding.[50] In addition, the canola varieties developed by the private sector would not have been possible without many years of public research on canola.[51]

Large seed companies focus on developing crops that are profitable for them, but not necessarily the best for farmers or for Canadians. Companies may prioritize producing seeds for crops that are planted on millions of acres, for example, but not invest in developing varieties that are well-suited to smaller regions with specific climatic conditions. Similarly, GM companies are foreign companies that have little financial interest in developing varieties suited to Canada's relatively small seed markets. **As plant breeding increasingly shifts into private hands, farmers pay more for seeds that are less well adapted to their regions and less resilient to change.**[52]

In addition, when private companies control breeding, returns go to shareholders, instead of back to the farm community and breeding programs.[53] Gray found that private seed companies reinvest a much smaller proportion of returns back into breeding research than public breeders.[54] This is despite the fact that these new crops are built on top of the work of public breeders who have developed conventional varieties, developed by government institutions and funded by Canadian farmers and public. Patented GM technology also makes it more difficult and more expensive for public institutions to conduct research. As Gray explains: "In some cases it is very costly to purchase the rights to use intellectual property. This drives up the cost of doing research and in some cases may block the development of new varieties."[55] Far from encouraging innovation, patents and private control over breeding can stifle the development of new agricultural research for the public good.

The shift to private breeding in Canada has also meant fewer resources are expended in agronomic research, which is research on agricultural practices rather than products. A 2014 study found that the agronomic research capacity in Canada is declining, and there is a need to reinvest resources for all types of farms and farmers.[56]

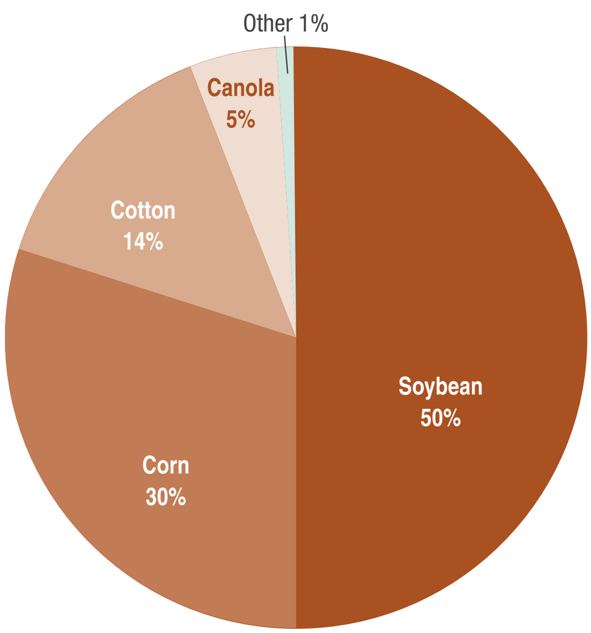
GM CROPS AND YIELDS

We often hear that GM crops are better for farmers because they produce higher yields. This claim is linked to the common assumption that higher yields lead to higher incomes for farmers. However, GM crops do not provide these benefits. This section counters the claims that GM crops increase yields, and the next section explores the ways in which GM crops have affected farm incomes.

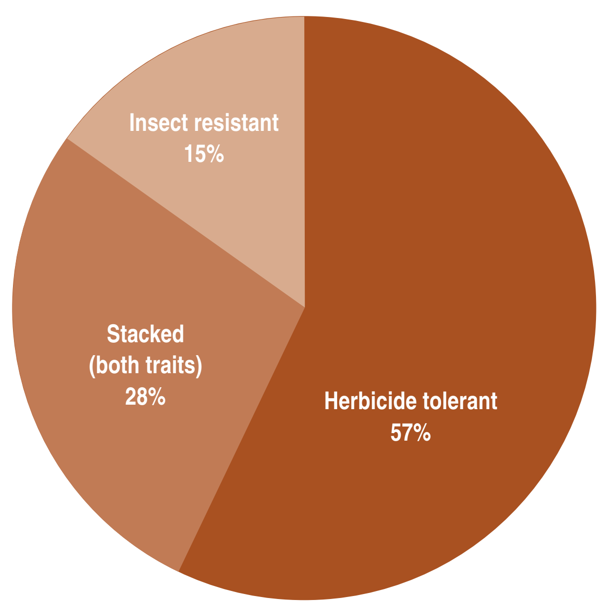
There are no GM crops engineered to produce higher yields. All claims that GM crops produce higher yields than non-GM crops are based on the assumption that the predominant GM traits of herbicide tolerance and insect resistance will decrease crop losses. Scientist Doug Gurian-Sherman explains the lack of GM traits specifically for yield by distinguishing between "intrinsic yield" and "operational yield."[57] Intrinsic yield is the potential or highest yield a crop can achieve under ideal conditions, while operational yield is the yield obtained in actual field conditions, with all the variable on-the-ground impacts of environmental factors, weeds and pests. There are no GM crops that have improved intrinsic yield.

Figure 2: Global GM crops and traits

GM CROPS AS PERCENT OF TOTAL GM AREA



GM TRAITS AS PERCENT OF TOTAL GM AREA



MAJOR GM CROPS	MINOR GM CROPS
1. Soybean	5. Alfalfa
2. Corn	6. Sugar Beet
3. Cotton	7. Papaya
4. Canola	8. Squash
	9. Eggplant

MAJOR GM TRAITS	MINOR GM TRAITS
Herbicide tolerance	Virus resistance
Insect resistance	Drought tolerance

See the GMO Inquiry report "Where in the World Are GM Crops and Foods?" for details.

Biotechnology and seed companies start with high-yielding non-GM crops, to which they then add GM traits. If a gene for insect resistance is added to a plant, for instance, it will be responsible only for making the plant toxic to certain insects. The yield traits of that plant are still determined by the pre-existing genetic characteristics of the non-GM variety into which the genetic sequence was inserted, and that was developed through conventional breeding methods. As Claire Robinson of GMWatch summarizes, "A high-yielding GM crop is a high-yielding non-GM crop with a GM trait added."[58]

Yields of a number of major crops have increased over the past century, in Canada and around the world. However, these increases are not due to the introduction of GM traits. Biotechnology companies claim that herbicide-tolerant and insect-resistant crops reduce losses to weeds and pests, and hence indirectly increase yields. However, this promise has not stood the test of the past twenty years. The clearest evidence of this is that the yields of GM and non-GM crops have increased at a similar rate in Canada, where GM crops are grown, and in other countries where they are not. These crop yield increases can be explained by improvements made through conventional breeding, in infrastructure, and in our understanding of agronomy and farm management.

> "The degree to which a farmer enjoys increased yields because of insect and herbicide tolerance traits will in large part be determined by how effective the farmer's weed and insect control programs were before planting a crop with these traits. If weeds and insects had been controlled well, then the insect and herbicide tolerance traits will not be the primary factor in increasing yield.
>
> — Monsanto[59]

CROP YIELD PATTERNS IN CANADA

> "GM crops generally have higher yields due to both breeding and biotechnology.
>
> — Monsanto[60]

Twenty years ago, when GM crops were first approved in Canada, famers were promised increased yields because of reduced losses to weeds and insect pests. Today, although new GM varieties continue to be commercialized with similar claims, these promises have not stood the test of time.

There is no independent, overarching analysis of the impact that GM crops have had on crop yield and productivity in Canada over the past twenty years. It is beyond the scope of this paper to provide a full literature review of existing studies or to do a complete statistical analysis. However, we can outline some preliminary information on trends in major crop yields in Canada over the past two decades, and experiences with GM crops in other countries. **This information challenges widely held assumptions about the benefits of GM crops on yields, and indicates that increases in crop yields over the past twenty years are due to conventional (non-GM) breeding and other factors, not GM traits. It also points to the need for further research and evaluation**.

We know that yields of major field crops in Canada – corn, soy, canola, wheat, barley and peas – have increased since the 1960s.[61] However, a comparison of yields, using 1964 as a base, shows that all these crops – those that have GM varieties and those that do not – show a very similar trend, with an increase of about 60%.[62] According to authors Richard Gray and Terrence Veemen, researchers at the Universities of Saskatchewan and Alberta respectively, the fact that yields for all these crops have increased so similarly, "is remarkable considering the varying locations, biological properties, farming systems, and research institutions associated with each crop."[63]

Data from Statistics Canada shows that, in the past twenty years, yields of crops with GM varieties – corn, canola and soybean – have not increased significantly more than those of major non-GM crops such as wheat, oats and barley. Between 1995 (when GM crops were approved in Canada) and 2014, for instance, yields of corn increased at a lower rate than yields of wheat. Soybean yields increased at a lower rate than wheat and oats, and at the same rate as barley yields. *(See Table 1)*.

Using Statistics Canada data, we can also compare the rate of yield increase before and after the introduction of GM traits. For instance, **in the case of soybean, average crop yields increased at a higher rate in the twenty years *before* GM crops were introduced than in the twenty years since**. Non-GM crops, such as wheat, continue to show significant yield increases, despite the fact there are no GM wheat varieties.

Table 1: Rates of crop yield increase per year in Canada

CROP	1975–1994 (BEFORE THE INTRODUCTION OF GM)	1995–2014 (AFTER THE INTRODUCTION OF GM)	
Corn	**1.2%**	**1.9%**	GM
Canola	**0.7%**	**2.4%**	GM
Soy	**1.6%**	**0.8%**	GM
Wheat*	0.6%	2.1%	NON-GM
Barley*	1.4%	0.8%	NON-GM
Oats*	1.3%	1.6%	NON-GM

** There are no GM wheat, oats or barley varieties on the market.*

Based on data from Statistics Canada, 2015[64]

It is worth noting that there is more than one way to calculate average rates of yield increase, and different methods reveal different results.[65,b] However, preliminary calculations show that **yields of GM crops have not increased at a higher rate than non-GM crops in Canada, and the introduction of GM varieties is not necessarily responsible for yield improvements**. These calculations and other research also show that **yields of non-GM crops like wheat have not stagnated without GM varieties**.[66] Moreover, they point to a need for an overarching and thorough evaluation of the impact that the introduction of GM varieties has had on crop yields in Canada over the past twenty years.

Although there is no evaluation of overall impact of GM crops on yields, there are studies on the yield effects of particular crops. In 2005, for instance, scientists in Canada found that Bt corn varieties produced up to 12% lower yields than their non-GM counterparts, took longer to mature, and had higher moisture rates.[67] They also found that the Bt varieties did not give any yield advantage over the non-GM varieties when damage by the European corn borer (the insect to which the Bt plant is engineered to be toxic) was low to moderate.

Yield gains in major crops can be explained by a number of factors other than GM traits. Corn yields, for instance, have increased significantly in the past sixty years.[68] According to a study published by the University of Guelph, these increases were due to a number of improvements in plant characteristics, such as an increased number of kernels per plant, more erect leaves and increased leaf area that can intercept light, and a longer period during which the plant stays green.[69] These improvements were achieved through conventional breeding. Changes in agronomic practices, such as earlier planting and longer growing periods, reduced row widths, fertilizer and pesticide use, and increased plant population densities, have also contributed to increased corn yields. Scientists estimate that, in general, 60% of yield increases in corn are due to improvements in plant breeding and genetics, and 40% due to agronomic practices.[70] On the ground, however, all yield increases are realistically due to the interaction between these factors.[71]

It is clear that improvements in crop yields in Canada cannot be assumed to be a result of GM traits. Retired University of Saskatchewan oat and barley breeder Brian Rossangel also makes this point. The reason that crop yields increased in Canada, he explains, is because of improvements in “plain old plant breeding.”[72] In the case of corn, for example, plant breeding developed varieties in which the leaves were more upright, allowing farmers to seed a lot more plants per acre. “The fact is that corn yields in Europe have gone up dramatically more than wheat yields in Europe and there sure as hell aren’t no GMOs involved in those European corn crops.” While Rossnagel believes GM crops do offer certain benefits, he also holds that “overzealous GM promoters” who claim that wheat yields are lagging because they do not have GM varieties, or that GM wheat will boost yields by 20-25%, are “overstating the case.”[73]

Overall yield patterns also do not reflect differences in crop performance from one region to another, or even from one field to another. For this reason, some farmers have seen yields increase in some years, while others may have seen a different pattern. Yield is affected by a number of factors including changes in the environment, fertiliser and pesticide use, agronomic practices and farm machinery.[74] Weather, for instance, has a major impact on yield, and weather differences are not always factored into yield calculations from one year to another. While genetics are often credited with increasing yields in good seasons and weather is often blamed for poor yields, the reality is a more complex mix of all these factors.

The figures discussed here show that there is a need for a broad and independent study to assess the impact of each of the four major

b The percentages discussed above are the result of exponential curve fitting analysis. When the same data are analyzed with a linear regression model, we see that corn yields have increased by 2.38 bushels per acre since 1995, in comparison to 1.18 bushels per acre in the twenty years before GM crops were introduced. In the past twenty years, wheat yields have increased by 0.80 bushels/acre on average, while canola yields have increased by 0.69 bushels/acre. The results are affected by typical yields for each crop and the time periods considered. In this research, we have considered the twenty-year periods before and after 1995, when GM crops were first approved. However, other moments in the history of crop development in Canada are also significant. In the early 1980s, for example, and again around 2000, new varieties of canola and wheat were introduced. (Graf. 2013. See endnote number 66). Dividing the time periods differently affects results.

GM crops individually, and of the overall impact of GM crops, on crop yields and productivity in Canada over the past twenty years. Such an analysis needs to separate out the effects of various factors – such as environmental conditions, crop genetics and production practices – on overall yields, in order to assess the possible contribution of GM traits to overall crop performance. This would allow farmers to assess whether possible benefits of GM crops outweigh their risks and costs. This analysis is also critical to assessing what role, if any, GM technology should play in our food and farming systems.

One of the challenges of evaluating the true impact of GM traits on crop productivity is that there are few non-GM acres left in Canada for the four major GM crop types. Approximately 95% of canola acres, over 80% of corn acres, and at least 60% of soybean acres in Canada are now GM.[75] GM sugar beet was introduced more recently, in 2009, and now all the white sugar beet grown in Canada is genetically modified to be herbicide-tolerant. Because of these high adoption rates, comparable data on the yields and performance of non-GM varieties of these crops is scarce. *See the GMO Inquiry report "Where in the World are GM Crops and Foods?" for more information*.

Studies from the US that explicitly look at the relationship of GM crops to yield and productivity patterns, and comparative studies on crop yields from North America and Europe, help fill in some of this missing information on the ways in which GM crops have affected crop yields.

Yield gains in major crops can be explained by a number of factors other than GM traits

CROP YIELD PATTERNS IN THE US

In 2012, scientist Doug Gurian-Sherman published the first study assessing the overall yield impact of the 13-year period of GM commercialization in the US.[76] This study found that GM crops had largely failed to live up their promise of increasing yields. While corn and soy yields in the US increased significantly in the past decades, these increases were due to improvements in traditional breeding and other agricultural practices, not GM traits.

GM herbicide-tolerant traits in the US have not increased – and may have decreased – overall soy yields. Gurian-Sherman concludes, "The typical pesticide regimes and combinations of several herbicides used prior to the introduction of glyphosate-tolerant soybeans were generally effective, if inconvenient, in controlling weeds. Glyphosate has been effective against many species of weeds, and therefore more convenient because farmers can often avoid using several different herbicides and spraying schedules, but it does not necessarily provide better weed control than several other herbicides combined."[77] Similarly, GM herbicide-tolerant corn did not provide a yield advantage over conventional corn varieties.[78]

In the case of GM insect-resistant Bt corn, Gurian-Sherman found that Bt corn provided 7-12% higher yields in years when infestations of European corn borer (ECB) were high, but no yield advantage when infestations were low to moderate, even when compared to conventional corn varieties that were not treated with insecticide. Overall, Bt corn (including with traits for rootworm resistance and ECB resistance) provided a 3-4% yield advantage over 13 years, or 0.2-0.3% yield increase per year.[79] This means that Bt corn is only economical for farmers in years of heavy infestation, because the Bt seed is more expensive. However, since infestation is not always predictable, farmers may often choose to buy Bt seed as a preventative measure, which may mean that they are buying more expensive seed for no yield advantage.[80]

A longer-term view of crop yield increases also shows that much of the historical yield increase in the US took place before the commercialization of GM crops, and was therefore due to conventional methods that bred traits such as several types of disease resistance.[81] These increases have also been attributed to improvements in irrigation, mechanization and fertilizer use.[82]

Studies of trial plots specifically comparing GM and non-GM crops have found similar results. In university trials of GM soybean conducted in the US in 2001, researchers found that GM glyphosate-resistant varieties gave 5%-10% lower yields than non-GM varieties.[83] The researchers found that this yield decline was due to the gene or its insertion process. Some years later, in 2009, to counter claims of low yields in GM soybeans, Monsanto released a new generation of high-yielding GM glyphosate-tolerant soybeans called Roundup Ready 2. However, a study found that growers and seed distributors felt the new variety did not meet their expectations.[84] In 2010, the state of West Virginia began an investigation of Monsanto for falsely advertising that Roundup Ready 2 soybeans gave higher yields.[85] The probe was part of a broader anti-trust investigation of Monsanto by the US Justice Department, but the investigation was closed in 2012, without reporting any findings.[86]

Similarly, a study of GM and non-GM corn grown in test plots at the University of Wisconsin between 1990 and 2010 found that, although some GM varieties reduced yield risk (by reducing the variation between crops grown in different conditions, for example by reducing the risk of loss to pests), most had the same or lower mean yields than the conventional varieties.[87] With the exception of Bt corn engineered to be toxic to the European corn borer, the authors say they "were surprised not to find strongly positive transgenic yield effects."[88] Several crops with multiple stacked GM traits also showed lower yields than their conventional counterparts, and several showed lower yields than the sum of yields from varieties with the corresponding single traits.

In a 2006 evaluation of GM crops in the US, the US Department of Agriculture (USDA) also found that GM traits themselves do not increase yields: "Currently available GE crops do not increase the yield potential of a hybrid variety. In fact, yield may even decrease if the varieties used to carry the herbicide-tolerant or insect-resistant genes are not the highest yielding cultivars."[89] An updated USDA report in 2014 says, **"Over the first 15 years of commercial use, GE seeds have not been shown to increase yield potentials of the varieties. In fact, the yields of herbicide-tolerant [HT] or insect-resistant seeds may be occasionally lower than the yields of conventional varieties if the varieties used to carry the HT or Bt genes are not the highest yielding cultivars, as in the earlier years of adoption."**[90] The 2014 report concluded that some Bt crops can reduce yield loss to pests, while Ht crops have had a mixed effect on yields; several studies have shown that Ht crops have no impact on yields, some have found a positive impact, and others have found decreased yields.[91] The USDA studies also found that US farmers primarily adopt GM crops to increase yields. Other reasons include decreasing pesticide input costs, saving management time, and making other farm practices easier.[92]

> "Commercial GE crops have made no inroads so far into raising the intrinsic or potential yield of any crop. By contrast, traditional breeding has been spectacularly successful in this regard; it can be solely credited with the intrinsic yield increases in the United States and other parts of the world that characterized the agriculture of the twentieth century.
>
> — Doug Gurian-Sherman[93]

Unlike traits for herbicide tolerance and insect resistance, most crop traits, including yield and drought tolerance, are more complex and determined by several genes and the interactions between them, not by any one gene or trait.[94] This is part of the reason why there are few crops with these GM traits in the pipeline, and even fewer that have been commercialized. Where they do exist, as in the case of drought-tolerant corn, the GM varieties are less effective and efficient than varieties developed through conventional breeding. In fact, farmers in Africa are already growing non-GM drought-tolerant corn varieties that show yield improvements of 20-30% over previous varieties.[95] Another 153 non-GM varieties that yield up to 30% more than existing commercial varieties under drought conditions are currently being trialled.[96] In comparison, Monsanto's GM drought-tolerant corn shows a 5-6% yield increase in the US, and only under conditions of moderate (not severe) drought.[97]

The fact that GM crops have not increased yields in the US – where the largest GM area in the world (40%) is grown, and where farmers have access to irrigation, fertilizers, pesticides and other inputs – throws doubt on the claim that GM crops will help smaller-scale and resource-poor farmers in the Global South.

CROP YIELD PATTERNS IN EUROPE

In Europe, where GM crops are not being grown (except for some areas in Spain, and very small areas in Portugal, Czech Republic, Romania and Slovakia, all of which cumulatively account for 0.08% of total global GM area), **patterns of yield increase in corn and canola over the past twenty years have been very similar to those in the US and Canada**.

A 2013 study by Jack Heinemann and others compared overall yield trends for corn and canola in North America and Western Europe (Austria, Belgium-Luxembourg, France, Germany, Netherlands and Switzerland), to assess whether yield trends showed any significant differences between years, locations, and the percentage of GM crops grown.[98] Both regions are at similar latitudes, have similar climate and other agricultural conditions, and corn is an important crop in both regions; the only major difference between the areas is that Western Europe is not growing GM varieties of corn and canola, while North America is growing very large amounts of both.

The authors found that between 1961 and 1985, the US had higher average yields for corn than Western Europe but that between 1986 and 2010, Western Europe had slightly higher average yields. For the entire period between 1961 and 2010, average corn yields in the US and Western Europe did not show any significant difference. **The authors conclude that "these results suggest that yield benefits (or limitations) over time are due to breeding and not GM ... because W. Europe has benefitted from the same, or marginally greater, yield increases without GM."**[99]

The authors found similar results even when they just analyzed the period during which a significant quantity of GM corn was grown in the US. Between 2001 and 2012, annual yields in the US were similar across the years.[100] In this same period, corn yields in Western Europe increased by more than five times the US rate. Between 2005, when over half of US corn hectares were GM,[101] and 2012, when 88% of corn hectares were GM,[102] average corn yields in the US declined, while they continued to rise in Western Europe. This means that even if a yield comparison were to "concentrate only on the period when the US was growing essentially all its GM maize [corn], we would find that the yields were decreasing or static, while Western Europe's yields increased significantly over this same period."[103]

In the case of canola, the authors found that the yield gap[c] is increasing in Canada, and yields continue to be higher in Western Europe. In fact, the overall yield difference has grown in the years since GM crops have been commercialized: Between 1961 and 1985, Canadian canola yields were lower by 1,100 kg/ha on average, while between 1986 and 2010, this difference grew to 1,730 kg/ha. This is despite the fact that approximately 95% of Canada's canola acres are planted with GM canola.[104] According to Heinemann, "Our research showed rapeseed (canola) yields increasing faster in Europe without GM than in the GM-led package chosen by Canada and decreasing chemical herbicide and even larger declines in insecticide use without sacrificing yield gains."[105]

c Yield gap is the difference between the estimated yield potential and the actual yield.

GM CROPS AND FARMER INCOMES

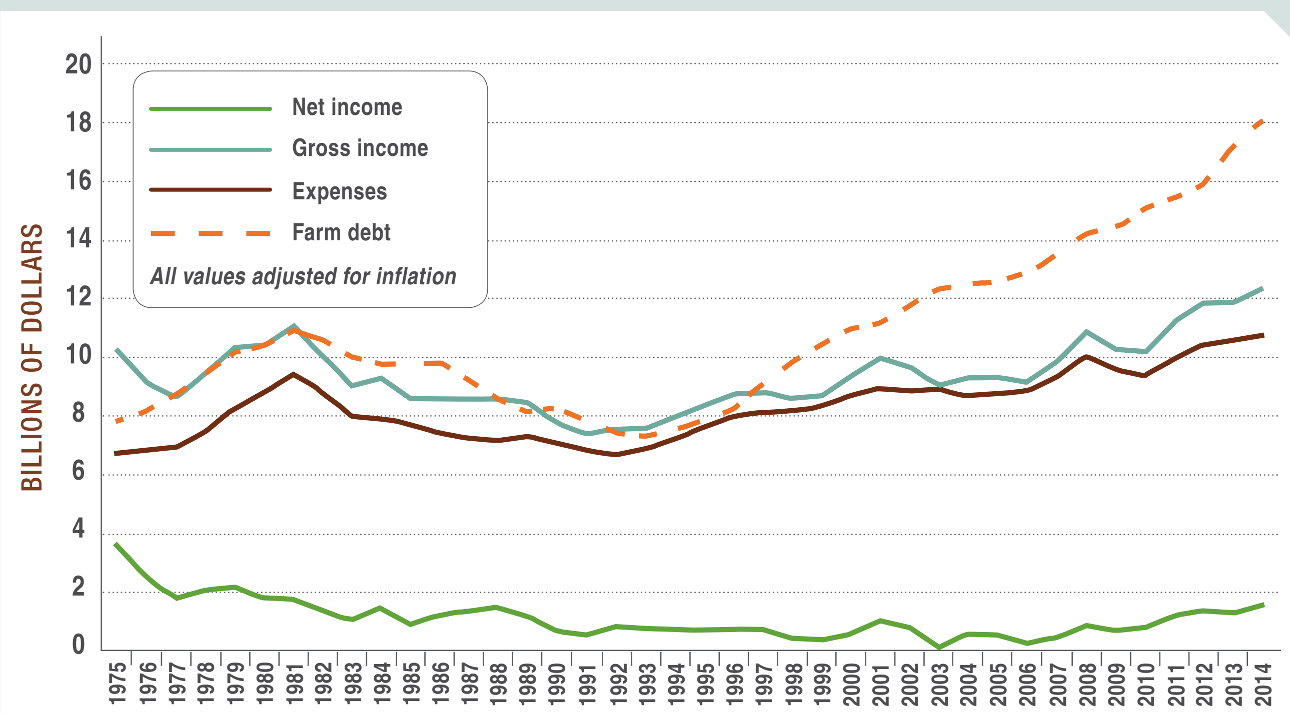
The overall profitability of farming is not based only on yields and the productivity of crops, but also on a number of broader, dynamic factors such as global and domestic commodity prices, currency exchange fluctuations, trade decisions, and other political and economic factors. The profitability of a crop depends on how far any benefits outweigh the costs of seed, pesticides and other inputs such as fertilizer and fuel, and land.

GM CROPS AND FARMER INCOMES IN CANADA

Growing GM crops is not putting more money into the pockets of Canadian farmers. Statistics Canada data shows that, although gross farm income in Canada has increased over the past two decades, realized net income (the income remaining after farm expenses are paid) has not changed significantly. As figure 3 shows, when adjusted for inflation, net farm income since 1990 has been lower than in the previous decades, and is lower today than it was in the late 1970s.

Farm expenses and debt in Canada have been climbing steadily since the early 1990s (See fig 3).[106] Over the past twenty years, expenses for farmers have more than doubled – from $25-billion in 1995 to $50-billion in 2014 (not adjusted for inflation).[107] In addition, farm debt has more than tripled in the same period. **Over the past twenty years, between 87% and 99% of gross farm income has gone towards paying farm expenses every year. In other words, net farm incomes have ranged from being just 1% to 13% of gross farm income**.

Fig. 3: Farm income, expenses, and debt in Canada (1975-2014)



Data from Statistics Canada, 2015[108]

Farm income in Canada in 2014

Total gross farm income:	**$57.4 billion**
Total farm expenses:	**$50.2 billion**
Total net farm income:	**$7.3 billion**
Total farm debt:	**$84.4 billion**

Data from Statistics Canada, 2015[109]
All values are in 2014 dollars.

This trend of low farm income can be explained, at least in part, by the fact that rising input prices have pushed farm expenses up. The increase in gross farm income has been absorbed by the growing costs of inputs such as fertilizers, chemical pesticides and other technologies, including expensive GM seeds. GM seed is significantly more expensive than conventional seed.

GM crops have also introduced new costs, from problems such as GM contamination and the faster evolution of herbicide-resistant weeds. These costs threaten to reverse or eliminate any benefits that GM crops may have offered farmers. *(See page 30 for more on the costs of contamination and page 24 for the costs of herbicide-resistant weeds*).

The cost of patented GM seed has climbed much faster than the cost of non-GM seed

SEED PRICES IN CANADA

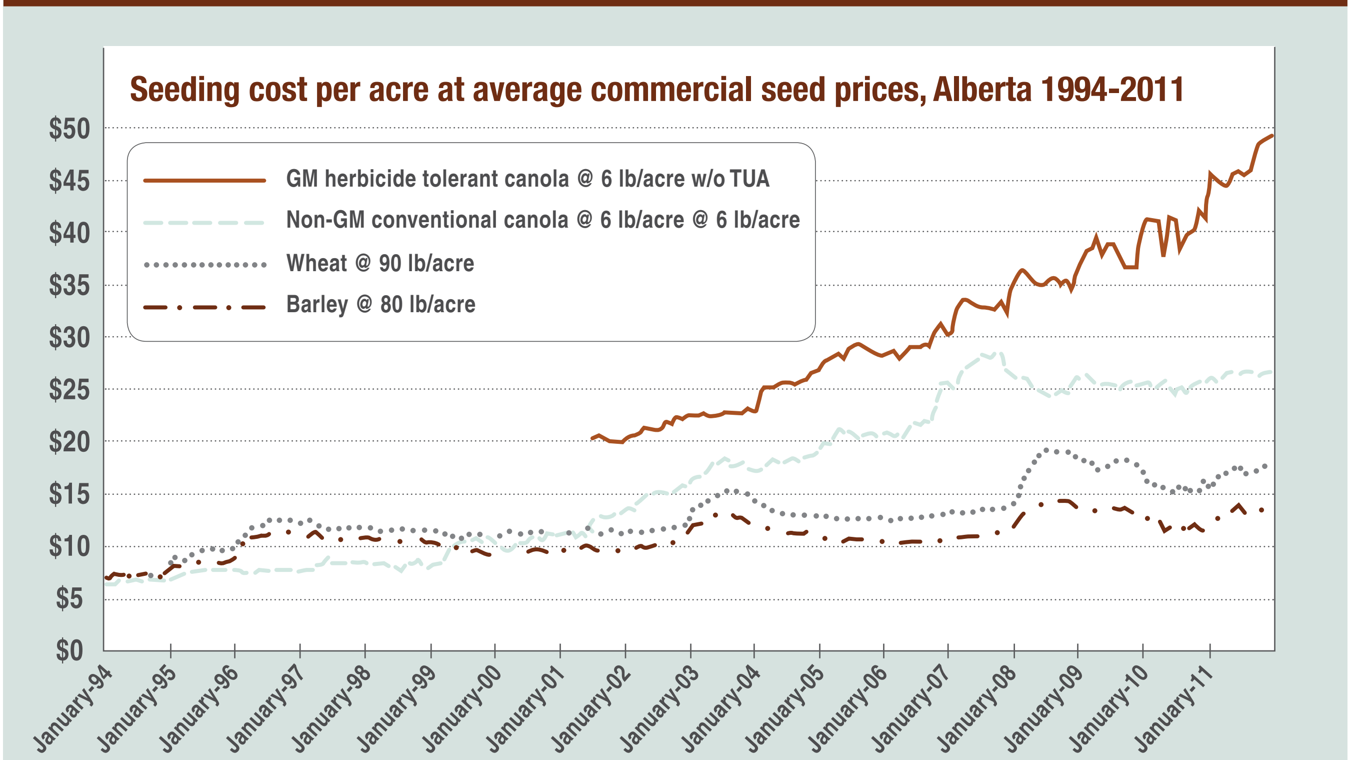
“The value of farm-saved seed cannot be overstated… Without control of our seed, we really do not have control of our farms.

— National Farmers Union[110]

The cost of seed in Canada has been rising steadily and accounts for a large portion of total farm expenses. In 1981, seed costs accounted for 2.5% of total expenses.[111] By 2014, this number had risen to 4.6% and is continuing to climb. In Saskatchewan, the cost of seed increased seven-fold between 1981 and 2011, from $50-million to $350-million.[112] **In 2014, Canadian farmers paid $2.3-billion for commercial seeds. Their total realized net farm income in the same year was $7.3-billion**.[113]

Seed costs are growing faster than the costs of other goods in Canada,[114] and have not gone up equally in all crops. **The cost of patented GM seed has climbed much faster than the cost of non-GM seed**. For instance, figure 4 shows the per-acre seeding cost in Alberta for wheat, barley, non-GM canola and GM herbicide-tolerant canola from 1994 to 2011. Costs for all four crops were similar until 2000, when canola prices started to rise much faster than wheat and barley. After 2007, GM canola seed prices continued to rise, while the price of non-GM canola did not. By 2009, almost all canola grown in Canada was GM (herbicide-tolerant), and by 2011, Alberta stopped reporting non-GM canola prices. The price of wheat and barley seeds has remained fairly constant over this entire period.

Fig. 4: Rising cost of seed prices in Canada



Graph from the National Famer's Union, 2013[115]

Initially, companies also charged a separate "technology use fee" along with GM seeds. Monsanto, for instance, added a $15/acre fee to its GM canola when it was first introduced in 1996 and this meant that Canadian farmers annually paid at least $260-million in technology use fees alone.[116] In 2012, Monsanto stopped charging this as a separate fee and built it into the cost of the seed instead ("in-the-bag" price).[117]

The practice of maintaining stocks of farm-saved seed can help keep seed prices under control. If commercial seed prices climb too rapidly or are too high, farmers are able to use their own seed.

However, farmers cannot save and replant seed from GM crops because seed companies have exclusive rights to control the use of seed engineered with their patented genetic sequence This means that farmers are forced to purchase seed every year, increasing their overall costs. It also means that seed companies can hike the prices of their seed every year. In addition, an increasing number of non-GM seed varieties are being deregistered and taken off the market by the same companies that market GM varieties, ensuring that farmers continue to buy expensive GM seed.

Higher yields ≠ higher income

Higher yields do not necessarily mean more money for farmers. Farm income is shaped by a number of factors. These factors mean that even when yields have increased in Canada, net farm income has not increased apace.

In the current global food system, the prices at which farmers sell their crops are often shaped by global commodity exchanges, which in turn are influenced by a number of factors, including global trade patterns and futures trading. Other industry players in the food chain, such as seed and input companies, grain companies and elevators, food processing companies and retailers often benefit more from yield increases than farmers. Higher yields and abundant stocks can depress prices, and these other players benefit by paying lower prices to farmers when yields are high. This means that if yields are high, farmers do not necessarily directly benefit. Final benefits to farmers are determined more by the margins that farmers make on their crop, than on absolute yield.

Irrespective of yields, only a small portion of our food dollars makes it into farmers' pockets. Of every $1 that a consumer spends, only 20 cents, on average, reaches the farmer.[118] This amount is even lower for processed foods. Wheat growers in Canada, for instance, see only 13 cents for a loaf of bread sold at the grocery store for $2-3.[119] The difference between the price paid by the consumer and the amount that reaches the farmer is money that goes to wholesalers, retailers, taxes and transportation costs. In 1964, these additional costs accounted for 29% of the total cost of food, but by 2004 they had increased to 43%.[120]

GM CROPS AND FARMER INCOMES IN THE US

GM crops have not consistently increased farm incomes in the US either. Net returns for farmers who grow GM Ht corn and soy, for example, are not significantly different than for those who grow non-GM varieties.[121] Similarly, researchers comparing the overall profitability of non-GM and GM varieties of cotton in the US state of Georgia found that non-GM varieties provided the same or better returns as GM varieties.[122] The authors concluded, "The fact that seed cost, which increases dramatically with trait-enhanced cultivars, did not positively influence returns, suggests that technology system per se did not provide greater returns."[123] In some cases, the production cost savings provided by the Bt and stacked GM varieties were only enough to cover the technology use fees that came with them.

The price of GM corn and soy seed in the US increased by 50% between 2001 and 2010, while GM cotton prices rose even faster.[124] **Overall, seed prices in the US have increased by 140% relative to 1994, while other input prices have increased by 80%.**[125]

COST OF A BUSHEL OF SEED

Non-GM soybean in 1996:	$14.80
Non-GM soybean in 2010:	$33.70
GM soybean in 2010:	$49.60

GM SOYBEAN SEED: 47% HIGHER THAN NON-GM SOYBEAN SEED

COST OF SEED FOR AN ACRE

Non-GM corn in 1996:	$26.65
Non-GM corn in 2010:	$58.13
GM corn in 2010:	$108.50 – $120

GM CORN SEED: 87-106% HIGHER THAN NON-GM CORN SEED

From Benbrook, 2012; based on data from the USDA.[126]

Monsanto's GM virus-resistant papaya is widely credited with saving Hawaii's papaya industry from a serious outbreak of the papaya ringspot virus.[127] Though the GM papaya protected the plants against this virus, its introduction resulted in lost export markets, dramatically lower prices for farmers, and widespread contamination of organic and non-GM trees. When GM papaya was introduced in 1998, the price of papaya declined by 35% and production fell by almost 34%.[128] By 2006, the total value of the Hawaiian papaya industry was half of what it was in 1995.[129] Even now that the major export market of Japan allows GM papaya, exports to Japan were only $1-million in 2011 – they were $15-million in 1996. When the outbreak of the virus was at its worst, production was still higher than it was ten years after GM papaya was introduced.[130]

GM CROPS AND FARMER INCOMES AROUND THE WORLD

GM crops have not met their promise to increase farmer incomes in the Global South either. In fact, GM crops, and especially Bt cotton, were promoted in Asia and Africa as being particularly helpful to small-scale, poor farmers. However, the reality on the ground has been very different. This is partly because – as is the case in other countries – yields have not consistently increased with GM crops, and because seed and input prices are significantly higher for GM crops.

In India, for instance, a packet of GM Bt cotton seeds can cost anywhere from three to eight times as much as the cost of non-GM hybrid seed.[131] Native non-GM cotton varieties are even cheaper. A study that compared the economic impact of a Bt cotton variety and non-GM cotton variety, both in rain-fed conditions in one Indian state, found that both generated similar net revenues.[132] When the GM cotton variety was cultivated with irrigation, it had higher yields than non-GM cotton varieties grown in rain-fed conditions, but net revenues were not significantly higher because farmers spent significantly more on seeds and inputs. Similarly, another study found that expensive GM seed and the irrigation needed to make it perform well both increase risks for small scale rain-fed cotton cultivation (which accounts for most cotton in India).[133]

In addition, Monsanto's virtual monopoly over the Indian cotton seed market means that farmers cannot find non-GM seed.[134] Few farmers have any choice but to buy Monsanto's Bt cotton. A number of farmers in the study mentioned above – 40% of the farmers in each group – said that the reason they did not grow the non-GM variety is because the seed is very hard to access.[135]

Farmers often have to take out loans in order to afford costly GM seed, and, if yields are low and they are unable to pay back their loans, they are pushed deeper into a cycle of poverty and dependency. This cycle, which began with the shift from traditional, farmer-saved cotton seed to more expensive, proprietary hybrid seeds, has been exacerbated by the introduction of even higher-priced GM seed.

When crops fail, the consequences can be dire for resource-poor farmers, their families and communities. High prices, debt cycles and crop failures have triggered thousands of farmers in the cotton-growing belt of India to commit suicide. Between 1995 and 2010, a total of a quarter of million farmers committed suicide in India.[136] A recent study found that "suicides in rainfed areas of south-central India are inversely related to farm size and yields and directly related to area of Bt cotton adoption, or more likely the combined high costs of Bt seed and insecticide."[137] In addition, pesticide use was higher in 2013 than in 2000, despite the fact that Bt cotton's main promise was to reduce the need for insecticides.[138]

Ten years after it was first commercialized, the Indian Parliamentary Standing Committee on Agriculture (2012) undertook an evaluation of farmers' experiences with Bt cotton in India. Their report concluded: "After the euphoria of a few initial years, Bt cotton cultivation has only added to the miseries of the small and marginal farmers." The committee called for a complete ban on open field trials of GM crops in India, until the country was able to develop a better regulatory and monitoring system.[139]

In South Africa, where GM corn was introduced in 1998, seed costs have steadily increased as the acreage under GM corn has grown. In 2004, when a fifth of corn seed sold was GM, seed costs accounted for 6% of corn farmers' total inputs costs. By 2011, when over three quarters of the total corn seed sold in South Africa was GM, seed costs represented 13% of input costs.[140] GM Bt corn in South Africa seed sells for approximately double the price of non-GM hybrid varieties, and five times the price of open pollinated varieties.[141] Seed costs for GM corn increased by 30-35% in just three years, from 2008 to 2011.[142]

High seed prices for GM Bt corn in South Africa have not been balanced out with higher incomes. Pressure from the stem borer, the insect that Bt corn targets, is extremely variable. In years of low insect pressure, farmers can face economic losses by planting Bt corn instead of non-GM hybrids.[143] In addition, the Bt corn varieties on the market are designed for large scale capital intensive farming that include high quality soil, sufficient rainfall or irrigation, fertilization and good storage conditions. Small-scale farmers often cannot provide such conditions. In fact, locally adapted non-GM hybrids and open-pollinated varieties have been found to perform better than the varieties that GM traits are inserted into.[144]

These examples show how patented GM crops can chip away at net farm incomes. In this way, **GM crops facilitate a transfer of wealth from farmers to seed companies, and further strengthen corporate control of our seed and food system**.

GM crops facilitate a transfer of wealth from farmers to seed companies, and further strengthen corporate control of our seed and food system

GM CROPS AND HERBICIDE-RESISTANT WEEDS

GM herbicide-tolerant (Ht) crops offered farmers a more convenient weed management system. Ht crops simplified herbicide applications for farmers by allowing them to use a single broad-spectrum product (such as glyphosate) across their fields to control a wide range of weeds, rather than managing and calculating the use of a number of different products and management practices. Cost, simplicity and convenience are the top three factors that farmers in the Global North consider when they are deciding which weed management approaches to use.[145] However, the emergence of weeds resistant to herbicides such as glyphosate has begun to reverse these management benefits. **Glyphosate-resistant weeds are reducing the effectiveness and convenience of glyphosate-tolerant GM crops, reducing yields when weeds are hard to control, and increasing herbicide use and weed management costs**.

The introduction and subsequent widespread adoption of GM herbicide-tolerant crops (which are engineered to withstand the application of a particular herbicide or herbicides, most commonly glyphosate) increased the frequency and amount of certain herbicides. Glyphosate is the top pesticide sold in Canada, and glyphosate use tripled between 2005 and 2011, climbing from 30.2 million litres to 89.7 million litres in Western Canada, and from 3.8 million litres to 12.3 million litres in Eastern Canada.[146] In 2012, more glyphosate was applied to fields in Western Canada than all other herbicides combined. **This increase and repeated use of glyphosate, combined with an overreliance on herbicides in general to control weeds,[148] increased the selection pressure on weeds and led to the evolution and spread of a number of glyphosate-resistant weeds**. *For details on the role of GM crops in the emergence of herbicide-resistant weeds, and for more information on the use and impacts of glyphosate, see the GMO Inquiry report "Are GM Crops Better for the Environment?"*

There are now 32 species of weeds that have been documented to be resistant to glyphosate in the world. Fourteen of these are found in the US, 10 in Australia, 7 in Argentina and 6 in Brazil.

Five species of glyphosate-resistant weeds have been found in Canada, and this number is increasing. An online survey of farmers in 2013 estimated that more than one million acres of Canadian farmland had glyphosate-resistant weeds.[149]

Table 2: Glyphosate-resistant weeds in Canada

NAME	LATIN NAME	PROVINCE	DISCOVERED
Giant ragweed	*Ambrosia trifida*	Ontario	2008
Canada fleabane	*Conyza canadensis*	Ontario	2010
Common ragweed	*Ambrosia artemisiifolia*	Ontario	2012
Kochia	*Kochia scoparia*	Alberta, Manitoba, Saskatchewan	2012
Tall waterhemp	*Amaranthus tuberculatus*	Ontario	2014

From weedscience.org, 2015[150]

The problem of herbicide-resistant (HR) weeds predates GM crops. The first instances of herbicide-resistant weeds were observed in the 1950s[151] with the introduction and wider use of industrial farming methods and chemical herbicides. As herbicide use has increased, so has the number and range of herbicide-resistant weeds. GM crops have accelerated and entrenched this pattern because the introduction of herbicide-tolerant crops, particularly glyphosate-tolerant "Roundup Ready" crops, has meant that larger areas of cropland are repeatedly sprayed with the same herbicide – glyphosate.[152] Other farming practices, such as chem fallow, increased use of no-till systems, and tighter crop rotations of herbicide-tolerant corn and soy also encourage the emergence of Hr weeds.[153,154]

The emergence of HR weeds was expected. Scientists, environmentalists and weed experts warned of the probability of weeds developing resistance to herbicides that were being used repeatedly in GM cropping systems when GM crops were first introduced.[155] Chemical and GM seed manufacturers however, assured farmers that since glyphosate had already been used for a long time without the development of resistant weeds, this would not be a significant threat. In 1997, for instance, Monsanto's scientists said, "it is reasonable to expect that the probability of glyphosate-resistant weeds evolving will not increase significantly over that considered with current use."[156] Although several weeds had developed resistance to other herbicides by the 1990s, few cases of glyphosate-resistant weeds had been documented, and glyphosate was marketed as a particularly challenging herbicide for weeds to overcome.[157]

COSTS AND IMPACTS OF HERBICIDE-RESISTANT WEEDS

HR weeds create a number of management problems and associated costs for farmers. Using extra herbicides or multiple herbicides together to control HR weeds increases weed management costs. The weeds compete with crop plants, and can decrease yields and increase harvest costs. Weeds that are resistant to multiple herbicides, or that have grown too large, can be hard to control even with herbicide mixes, and may require manual removal, further increasing farm costs. Volunteer herbicide-tolerant crops that emerge in subsequent crop rotations also pose similar problems and have to be managed as HR weeds. In the US and Australia, HR weeds have decreased the value of cropland.[158]

Hugh Beckie, a weed expert and scientist with Agriculture and Agri-Food Canada, estimates that herbicide-resistant weeds cost growers in Canada $1.1-billion to $1.5-billion per year.[159] He also warns that herbicide resistance is continuing to spread. Beckie estimates that the number of hectares in the Prairies with at least one HR weed has increased from 4.4 million in the early 2000s to 15.4 million in 2014.[160]

GLYPHOSATE-RESISTANT WEEDS IN CANADA

Not all weeds are the same. The biology and geographical range of each weed species determines where and in which crops it is most commonly found, whether or not it develops resistance, its impact on the crop, and how easy it is to control.

GIANT RAGWEED

In Canada, giant ragweed is typically found only in Southern Ontario.[161] Weed experts believe that changes in crop rotation have encouraged giant ragweed growth.[162] Up until the 1990s, when wheat and corn were the major crops in the province, giant ragweed was a minor problem, and was largely confined to ditches. However, when soy, which competes poorly with giant ragweed, became more widespread, the weed became more common in fields, and gradually also developed resistance to glyphosate.[163]

Poor control of giant ragweed can result in large yield losses: one plant per square meter can reduce soybean yields by 77%. In corn, 14 plants per square meter can reduce yields by 90% if the weed and crop emerges at the same time.[164]

Glyphosate-resistant giant ragweed has been found to survive very high doses of glyphosate.[165]

Giant ragweed has now developed resistance to multiple herbicides, making it more complicated to control.[166]

CANADA FLEABANE

HR Canada fleabane (also called horseweed, mare's tail, coltsweed and butterweed) has become a major problem for farmers in Ontario. Fleabane has a wide range and spreads rapidly, producing up to one million small seeds per plant, which can travel up to 500 km.[167] It was first found to have developed resistance to glyphosate in 2010 and then spread 800 kilometres in just four years.[168] In a 2013 online farmer survey, Ontario farmers estimated that 72,800 hectares (179,890 acres) of their farmland was infested with glyphosate-resistant fleabane.[169]

Researchers in Michigan have found that 150 Canada fleabane plants per square metre can reduce soybean yields by 85%.[170] In some parts of Ontario, the weed has developed resistance to paraquat and other herbicides as well,[171] making it particularly challenging and costly to control, though it can be controlled with tillage as well.[172]

COMMON RAGWEED

Common ragweed is a widespread weed in North America. It can produce up to 64,000 seeds per plant, and seeds can stay dormant in the soil for years.

Common ragweed infests soybean, and glyphosate-resistant common ragweed can cause substantial soybean yield losses. Four common ragweed plants in 10 square metres have been reported to cause a 132 kg/ha yield loss in soybean.[173] Common ragweed has also been found to be resistant to multiple herbicides.[174]

KOCHIA

Herbicide-resistant kochia has been reported in Manitoba, Alberta and Saskatchewan and scientists predict it could have a more negative impact on crop yields than palmer amaranth has had on US crops.[175] Kochia can grow up to 6-8 feet, and glyphosate-resistant kochia can eventually destroy a crop.[176] If allowed to reach maturity, a kochia plant can produce 25,000 seeds,[177] making it a very fast-spreading weed. The stem of the plant breaks off in the fall so it can become a tumbleweed, spreading seeds as it rolls.

One kochia plant per 16 feet of sugarbeet can reduce yields by 12%. For other crops, such as flax and pulses, "the plant can be devastating, choking out broadleaf crops for sun and moisture."[178] Kochia has also developed resistance to some group 2 pesticides, and in the US, to group 4 and 5 pesticides in some states as well, making it increasingly harder to control.[179] A study from the US published in September 2015 confirmed the first case of kochia that is resistant to four herbicide sites of action.[180]

TALL WATERHEMP

Waterhemp can produce 300,000 seeds per plant, and one plant has been documented to produce as many as 5 million seeds.[181] It has been found to survive up to six times the normal application rate of glyphosate.[182] Seeds can stay viable for four years. Waterhemp can reduce corn yields by 15% and soybean yields by 44%.

Waterhemp has also developed resistance to other herbicides in Canada. In the US, it is the first broadleaf weed species that has been found to be resistant to all five classes of herbicides, and according to weed specialist Aaron Hager, it "has the potential to become an unmanageable problem."[183]

EVEN MORE GLYPHOSATE-RESISTANT WEEDS

Canadian weed scientist Hugh Beckie predicts that there are other weeds that may be at risk of developing resistance to glyphosate. There are a number of factors that make some weeds more likely to develop resistance than others, of which herbicide selection pressure – how much of a herbicide is applied, how long it lasts in the soil, and how often it is applied – is the most important. This is why GM glyphosate-tolerant crops pose a significant risk: the GM technology encourages the use of glyphosate in large quantities and over large areas, and often several times a year.[184]

Beckie predicts that wild oats may be the next weed to develop resistance to glyphosate. Wild oats are already resistant to a number of other herbicide classes in Canada and will be very difficult to control if they also develop glyphosate resistance. Other weeds that are at risk of developing resistance in Canada include green foxtail, cleavers, and wild buckwheat.[185]

Some weed experts predict that palmer amaranth, which is not currently found in Canada, is also heading northwards. Herbicide-resistant palmer amaranth has become a major problem for farmers in the US, and weed experts warn that it will be in Canada within the next two or three years.[186] Palmer amaranth can produce more than one million seeds per plant and spreads very fast. The seeds from a single glyphosate-resistant plant can completely take over small fields in just two years[187] and can cause 78% yield loss in soybean and 91% yield loss in corn.[188] Often, the spread of the weed can make a crop impossible to harvest, causing complete crop loss.[189]

GLYPHOSATE-RESISTANT WEEDS IN THE US

Glyphosate-resistant (GR) weeds emerged earlier in the US and are more widespread than in Canada. The impacts they have had act as a warning for farming systems north of the border. In 2013, the USDA estimated that 70 million acres of US farmland had GR weeds.[190] In 2014, the industry association CropLife reported that approximately half of US growers said that hard-to-kill weeds were a “major problem” in their crop fields during the 2013 growing season.[191]

Some of these weed species can grow to be very large (8-10 feet) and have strong stems that can damage farm equipment. Some can produce hundreds or even thousand of seeds, and some seeds can remain viable for up to 50 years.[192] In 2011, farmers in the Midwest were forced to hire workers to manually cut weeds whose stems were four inches in diameter.[193]

The rapid spread in GR weeds over the past decade in the US has been a costly problem for farmers. Many buy extra herbicides to try to control resistant weeds. In 2014, Monsanto’s net sales for herbicides grew by 13% from the year before, and their prices spiked by 10%.[194] CropLife reported that an Arkansas farmer’s weed management costs grew from $12-$15 an acre in a few years to $65-$80 by 2010, due to increased herbicide, labour and fuel costs.[195] Similarly, herbicide costs to control palmer amaranth in cotton fields have climbed from $23 an acre in 2004 to $100 per acre in 2012.[196] Overall, researchers estimate that **controlling herbicide-resistant weeds costs growers in the US approximately $2-billion**.[197] Infestations of glyphosate-resistant weeds in some cotton growing areas in the US were severe enough to force farmers to leave fields unharvested, and weed management costs in infested fields were 50-100% higher per hectare than in fields without GR weeds.[198] In 2008, Monsanto began offering farmers in the US rebates towards the costs of buying the non-glyphosate herbicides they needed to control and prevent the spread of glyphosate-resistant weeds.[199]

Glyphosate-resistant palmer amaranth now infests 61% of Arkansas soy acres and 87% of its cotton acres.[200] Fifty percent of Arkansas’ cotton fields are now hand weeded. Some farmers have lost their fields entirely. Now some Arkansas cotton growers pay up to $250 an acre to get their fields hand weeded.[201] Similarly, scientists at the University of Tennessee studied farms in that state and found that for soybeans and cotton, herbicide-resistant weeds cost farmers at least $200-million in additional herbicide and application costs and yield loss. They called this “an absolutely staggering figure.”[202]

Agriculture Canada weed scientist Neil Harker explains that Canada is a few years behind the US in terms of selection pressure on weeds: “If we go to the same intensity with one, single-trait rotation like RR (Roundup Ready) corn, RR cotton, RR soybean like they have, which we have the potential to do in Western Canada… we’re going to be in a similar situation.”[203] Harker also argues that it is important to take action soon: “We’re approaching a cliff…. If we don’t take steps to stop weed resistance we’ll fall back on a time when all weeds were hand weeded. Every time herbicides are used in any setting, weeds evolve by developing resistance.”[204]

LOOKING AHEAD

The spread of glyphosate-resistant weeds is reducing the efficacy of glyphosate, and in time may make it useless. As they spread, resistant weeds are undoing any weed management benefits that herbicide-tolerant crops may have offered farmers, and any environmental benefits that associated conservation tillage may have presented.[205]

In addition, no new synthetic herbicides have been commercialized in the past two decades, and there are none that will be commercialized any time soon.[206] The widespread adoption of herbicide-tolerant crops and glyphosate's consequent capture of the market have meant that pesticide companies have not been investing to develop new herbicides since the mid-1990s.[207]

According to Charles Benbrook, "The reality of weed management without the silver bullet of glyphosate is that we need to revert to a many-hammers approach — crop rotations, cultivations, tillage, appropriate herbicide application...It's going to take more time, it will take more management care, and it will probably cost more money."[208] Other scientists agree. According to scientists Dale Shaner and Hugh Beckie, "Attempting to manage herbicide resistance solely with herbicides is doomed to failure."[209] Farmers also seem to feel similarly. According to the polling company Stratus Ag Research, "Eighty-nine percent of [Canadian] farmers are willing to change their farming practices on their farm to prevent resistance."[210]

Weed scientists are increasingly recommending an "integrated weed management" approach to replace the current over-reliance on a few herbicides. Such an approach includes a number of non-herbicide strategies for weed management such as diverse crop rotations, use of cover crops and green manure crops, higher crop seeding rates and other practices to slow the evolution of resistant weeds.[211] Other scientists, including Orla Nazarko, Rene Van Acker and Martin Entz, argue that there are definite possibilities for herbicide reduction in Canada. They hold that the only long-term approach to sustainable weed management lies in shifting to a fundamentally different agricultural system; one that is more diverse, integrated and resilient, and that uses a multitude of non-chemical practices to preventatively reduce weed populations.[212] Ecological and organic farmers already employ a number of these practices, such as timely tillage, management of soil nutrients, cover cropping and longer crop rotations, to control weeds.

One barrier to the wider adoption of non-herbicide based management approaches is that few researchers are studying these strategies. Another is that despite what weed scientists recommend, growers are not always willing or able to adopt such strategies if they appear costly or time consuming. This can be because many large farming operations rely on maintaining cash flow, which often requires large amounts of land, and in turn requires increasingly simple management approaches. Dale Shaner and Hugh Beckie argue, "Because of the risky nature of farming, it is difficult for many growers to think long-term when the economic viability of their farm enterprise is at stake."[213]

The US Environmental Protection Agency is assessing a proposed management plan that includes restrictions on the use of glyphosate, to prevent further spread of glyphosate-resistant weeds. However, US weed scientist Mike Owen says such a plan may be too little, too late. "That horse has already left the barn," he said. "We probably needed this about 15 years ago."[214]

RESPONSE TO RESISTANCE: 2,4-D AND DICAMBA-TOLERANT CROPS

As glyphosate-tolerant crops become increasingly ineffective due to the emergence of glyphosate-resistant weeds, and with no new herbicides on the horizon, the seed and pesticide industry is encouraging farmers to use other herbicides, and to adopt new GM Ht crops that are tolerant to older herbicides such as 2,4-D and dicamba (often these are also stacked with tolerance to other herbicides, including glyphosate).

Canada was the first country in the world (in 2012) to approve 2,4-D-tolerant crops (corn and soy developed by the company Dow AgroSciences) and dicamba-tolerant soy (developed by Monsanto). Dow has genetically engineered "Enlist" corn and soy to tolerate its "Enlist Duo" herbicide that combines glyphosate and 2,4-D choline. The Enlist corn seeds will also be stacked with Monsanto's Roundup Ready Corn 2 and SmartStax.[215] (So far, the 2,4-D-tolerant corn has only been in limited production in Canada and the US, restricted to on-farm use for livestock feed,[216] and while Monsanto's dicamba-tolerant soy has been approved, it is not yet on the market).[217]

According to the U.S. commercial leader for Enlist, "Enlist Duo herbicide will help solve the tremendous weed control challenges growers are facing."[218] However, weed scientists do not agree.

Charles Benbrook has predicted that widespread use of 2,4-D-tolerant crops in the US could increase herbicide use by another 50%, and lead to weeds developing resistance.[219] According to the USDA, cultivation of 2,4-D-tolerant corn and soy in the US will increase 2,4-D use by 75%-300% by 2020.[220] Weed experts warn that weeds will, in fact, become resistant to 2,4-D, further perpetuating the pesticide treadmill that GM crops are encouraging.[221] Environmental scientists have argued that increased use of 2,4-D could have a number of environmental impacts on mammals, plants and pollinators.[222] In 2012, seventy doctors, nurses and health professionals submitted a letter to the US Environmental Protection Agency, warning that 2,4-D could be linked to a number of serious potential health impacts, and requesting the GM crops not be approved.[223]

Reminiscent of Monsanto's promises for glyphosate-tolerant crops, Dow says that weeds are unlikely to develop resistance to 2,4-D, and to crops with stacked herbicide tolerances.[224] However, there are already 16 species of 2,4-D-resistant weeds around the world (four in the US and two in Canada) and six species resistant to dicamba, (two in the US and two in Canada).[225] Weed scientists warn that the usefulness of the new herbicide-tolerant crops will consequently be limited and short-lived. According to Canadian scientists Hugh Beckie and Linda Hall, "Cultivars with stacked-HR traits (e.g., glyphosate, glufosinate, dicamba or 2,4-D) will provide a short-term respite from HR weeds, but will perpetuate the chemical treadmill and selection of multiple-HR weeds."[226]

Using herbicide mixes and growing crops that are tolerant to multiple herbicides will exacerbate and speed up the spread of weeds that are resistant to multiple herbicides.[227] In an opinion piece published in 2014, six Canadian and US scientists asked: "Why are so many weed scientists and extension personnel recommending more herbicides to mitigate herbicide resistance problems?... Are we as a discipline so committed to maintaining profits for the agrochemical industry that we cannot offer up realistic long-term solutions to this pressing problem?" The authors warned that crops stacked with multiple herbicide tolerances will lead to weeds with multiple tolerances, and can also lead to a number of environmental impacts. They call for research on alternative weed management methods and conclude: "…weed resistance to glyphosate and other herbicides is a 'tsunami' still out to sea but approaching land. The time has come to consider herbicide-frequency reduction targets in our major field crops – not just for environmental reasons but for economic reasons."[228]

The widespread cultivation of GM glyphosate-tolerant crops has driven the spread of glyphosate-resistant weeds. Replacing glyphosate-tolerant crops with others that are tolerant to different herbicides will only perpetuate a pesticide treadmill that is costly for farmers, and will worsen over time.

Bt-resistant insects

Farmers around the world who are growing GM insect-resistant (Bt) crops are also facing costly problems as insects are developing resistance to the Bt toxin. We have not seen Bt-resistant pests in Canada yet. However, Canada has a number of similar crop pests to those found in the US where resistance has developed, and much of the GM grain corn we grow in Canada is stacked with a Bt trait. Researchers in Canada have warned that there is no reason that resistance could not develop in insects in Canada as well, if the use of Bt crops continues. *See GMO Inquiry's report "Are GM Crops Better for the Environment?" for more details on the emergence of Bt-resistant insects*.

GM CROPS AND CONTAMINATION COSTS

Genes from GM crops can escape and spread to other plants and fields. Once released into our environment, genetically modified organisms can be difficult, even impossible, to control and recall. This GM contamination – which the industry calls adventitious presence – can come with a number of serious economic consequences for farmers. Contamination means that farmers can lose control over their seeds, fields and farms. They can lose their own seed stock and often bear the costs of testing, removing contamination, and preventing further contamination. Farmers also risk losing markets, including important export markets, if the contaminating GM crops are not approved in importing countries.

Farmers and scientists have identified a number of ways in which different GM organisms can escape and proliferate. Over time, it is hard – and often impossible – to completely prevent GM traits from escaping. The cost of prevention is borne by those farmers whose livelihoods are threatened by contamination. Organic farmers, for example, implement extra measures to prevent GM contamination (use of GMOs is prohibited in organic farming).

Each GM crop presents a unique contamination risk because each crop has different biological mechanisms that facilitate or hamper contamination. The contamination risk is also determined by the level of commitment on the part of industry and farmers to contain GMOs. In the case of soybeans, for example, farmers in Canada have been able to maintain non-GM soy production because of the plant's biology (soy is self-pollinating and has big seeds) and Canada's identity preservation system, which segregates certain high-value soy varieties for important international markets. Canola is considered a "high risk" crop for contamination since it is pollinated by wind and insects, can cross with volunteer and feral plants, and can spread through seed, while corn, which is wind pollinated, is considered "medium to high risk."[229] However, there are some common risk factors across all crops, the most obvious of which is human error. [230]

There have been a number of cases of GM contamination in Canada, and hundreds recorded across the world. Some of these incidents have had serious negative impacts on farmers. These cases offer important warnings about the contamination that can be expected with the release of genetically modified organisms, and the possible impacts on farmers and the environment.

GM FLAX

The GM "Triffid" flax was developed at the Crop Development Centre at the University of Saskatchewan in Canada, to be resistant to soil residues of sulfonylurea herbicides such as DuPont's "Glean" herbicide. It was approved in Canada (and the US) in 1998.

However, Canadian flax farmers were concerned that the GM flax would contaminate exports bound for Europe where the GM flax was not yet approved. To avoid the risk of market rejection, by 2001, farmers convinced the University to de-register the GM variety, effectively removing it from the market. At the time, GM flax seed was being prepared for its first sale to farmers – about 40 seed growers had multiplied around 200,000 bushels of the GM flax seed for future use – but these stocks were ordered to be crushed.[231]

Despite these measures, almost 10 years later, in September 2009, Triffid was discovered in Canadian flax export shipments, and ultimately reached at least 35 countries that had not approved the GM flax for environmental release or human consumption.[232] The source of the GM flax contamination has not been established.

IMPACT ON EXPORT MARKETS

The economic consequences of flax contamination were severe for Canadian growers. Canada is the world's leader in flax production and export; flax is one of Canada's five major cash crops, along with wheat, barley, oats and canola. In late 2009, the European market, which accounted for 68% of Canada's flax exports, was closed to Canadian flax.[233] Cash bids for flax in Manitoba dropped from about $9.90 a bushel to $6.78 a bushel (a 32% reduction) even before contamination was officially confirmed.[234] Flax acreage in Canada was down by 47% the year after contamination was found[235] and has not entirely recovered.[236] After five years, Canada is still struggling to regain its European market (25% of Canada's export in 2012/13).[237] The total cost of this contamination incident to the Canadian industry is estimated at $29.1-million.[238]

In 2010, the Canadian government pledged $1.9-million to develop methods to test flax seed for GM contamination.[239] For a time, thanks to subsidies, approved labs were providing a 50% discount to farmers for testing costs.[240] However, farmers are still bearing the long-term costs of GM flax contamination. Farmers have to pay to test all seed before they plant it, or buy new, certified seed, surrendering their farm-saved seed.

Under the auspices of cleaning up the contamination, grain company Viterra attempted, but failed, to require flax farmers to buy and plant only certified seed[d] for the 2010 crop destined for the European market.[241] Part of the reason farmers were ultimately not required to buy certified seed was because Triffid was discovered in pedigree and breeder seed as well.[242] However, the industry began a process of rebuilding its flax varieties and in 2013 released its "Reconstituted Flax Seed Program," which encouraged farmers to buy seed from certified re-constituted supplies.[243] Before 2009, about 75% of Canada's flax farmers used their own farm-saved seed.[244]

www.cban.ca/flax

d Certified seed is seed that is certified to be true-to-type. It is inspected by a third-party agency, to meet quality assurance requirements of varietal purity, germination and freedom from impurities.

GM CANOLA

Herbicide-tolerant canola was the first GM crop approved for growing in Canada, in 1995. The early adoption of GM canola by farmers in Canada was high, and so was contamination of non-GM canola. GM traits were found in volunteer canola plants as early as 1998 and testing found that by 2003 Canada's pedigreed canola seed production system had high contamination levels.[245] By 2007, GM traits were documented in escaped and feral roadside populations,[246] and by 2010, feral canola was widely found to be tolerant to both glyphosate and glufosinate in the Prairies, where it is produced[247] as well as in ports such as Vancouver, from where it is shipped overseas.[248] Approximately 95% of Canada's canola is now GM.[249]

Contamination from GM canola was so widespread in Canada that, by 2002, most, if not all, pedigreed seed growers in Saskatchewan would not warrant their canola seed stocks as GM-free.[250] Furthermore, most, if not all, grain farmers in Saskatchewan could not guarantee that their canola crop, even if planted with GM-free seed, was free from GM contamination.[251]

In 2002, government researchers found 59% of the lots of certified canola seed they tested in Saskatchewan were contaminated.[252] A year later, certified canola seed stocks were tested and 14 of the 27 unique, commercial certified canola seedlot samples failed the 99.75% cultivar purity guideline for certified canola seed.[253] The case of GM canola shows that, even with the pedigreed seed sector's strict varietal purity management control systems and the economic incentive to ensure that these controls work, the seed industry was unable to prevent contamination.

A 2003 survey of Canadian farmers growing genetically modified canola found that most farmers felt that it was not possible to control herbicide-tolerant traits from spreading in the environment and that methods like segregation, good farm practices - and even the idea of Terminator sterile-seed technology - could not control contamination.[254] **Farmers ranked loss of markets as the most important risk of growing GM canola**.

> "The loss of [European] markets due to GM's had a huge financial impact. This was likely larger than cost of controlling volunteers or benefit of easy weed control.
>
> —Manitoba farmer, 2003 survey[255]

IMPACT ON ORGANIC FARMERS

The unintended presence of GM canola in organic canola fields in Canada could not be detected before harvest, nor could it be prevented because of the biology of canola and its prevalence on Prairie farms. Buyers in the organic market tested for the presence of GM canola and did not accept contaminated lots. Seed contamination also quickly became an issue. Ultimately, except for a few isolated areas where other farmers do not grow canola, certified organic farmers lost the ability to grow, sell and export organic canola.

GM canola from neighbouring farms also increasingly appeared in certified organic fields where other crops such as wheat, oats or peas were being grown. In order to maintain or re-establish certified organic status for their crops, fields or farms, organic farmers had to manually remove the GM canola plants as well as implement additional measures to avoid contamination of current or future crops. The costs of implementing these measures were borne by the affected farmers.

GM canola contamination spurred a legal case from farmers seeking redress for contamination. In 2002, the Organic Agriculture Protection Fund (OAPF) of the Saskatchewan Organic Directorate filed for certification of a farmer class action lawsuit seeking compensation from Monsanto and Bayer (formerly Aventis) for GM canola contamination.[258] The claim alleged that when Monsanto and Aventis introduced their GM canola varieties, they knew, or ought to have known, that the genetically modified canola would spread and contaminate the environment, and that the companies had no regard for the damage these crops would cause to organic agriculture. The OAPF held that the loss of canola as an organic crop robbed organic farmers of a high-paying and growing market.[259] The class action was not certified in Saskatchewan and the Supreme Court would not hear the appeal, and so, in 2007, the legal action ended without actually being heard in the courts.

GM contamination costs for organic farmers

Not all farmers pay equally when GM contamination occurs. Non-GM farmers are largely responsible for preventing contamination from taking place, and when it does, have to bear the brunt of its impacts. Organic farmers, in particular, can pay a heavy toll for GM contamination because organic farming prohibits the use of GM seed.

Organic grain farmers in Canada have largely stopped growing canola due to contamination from GM varieties. GM alfalfa, which has been approved in Canada and could be put on the market in the near future, also poses serious risks for organic farmers. Such GM contamination threatens the future of organic farming; and so threatens the future of an important and growing sector. Between 2001 and 2011, for instance, while total farms in Canada declined by 17%, the number of organic farms grew by 66.5%.[256] The value of the organic food market has tripled since 2006 and currently accounts for $3-billion a year.[257]

Farmers in the courts

> "What it means to farmers all around the world is the loss and right to use your own seed… My rights as a farmer have been taken away because now I can no longer grow canola under fear of a lawsuit.
>
> — Saskatchewan farmer[260]

> "If biotech companies are entitled to monopoly rights over their patented genes wherever they occur, according to the Canadian Supreme Court Schmeiser vs. Monsanto decision, then we assert that these companies must also be liable for the losses due to the unwanted presence of these patented genes.
>
> — Organic Agriculture Protection Fund[261]

The liability issues raised by Saskatchewan organic farmers have still not been resolved in any court in Canada. As the lawyer for the class action described at the time, "This case seeks to ask whether biotechnology companies incur responsibility when their patented genetically modified seed, pollen and plants infiltrate farmland, causing harm. While Monsanto Canada Inc. v. Schmeiser confirmed that these companies have significant exclusive rights to GMO seed and plants – the question remains whether they have any corresponding duties."[262]

The *Monsanto Canada Inc. v. Schmeiser* case refers to the famous case brought by Monsanto against Saskatchewan canola farmer Percy Schmeiser.[263] The farmer was found guilty of having Monsanto's patented genetic sequence in canola on his land, and not having advised Monsanto to come and remove the GM plants. The court held that Monsanto had the right to their patented genetic material, even though the company could not prove how it got onto the farm. In this case, the courts were not ruling on the question of liability for accidental contamination. The case did, however, confirm that the patent over a genetic sequence applies to the whole organism that hosts it.[264]

A 2011 court challenge brought by over 60 family farmers, seed businesses and organic agricultural organizations in the US, and some from Canada, attempted to pre-emptively sue Monsanto, in order to protect themselves from being accused of patent infringement should they ever become contaminated (*Organic Seed Growers and Trade Association, et al., v. Monsanto Company, et al.*).[265] In 2014, the US Supreme Court upheld Monsanto's claims on GM seed patents and Monsanto's lawyers reiterated that, "Monsanto never has and has committed it never will sue if our patented seed or traits are found in a farmer's field as a result of inadvertent means."[266]

THE COSTS OF FUTURE GM CROPS

GM WHEAT

In 2002, Monsanto submitted applications for approval of its GM herbicide-tolerant (Roundup Ready) wheat in Canada and the US. However, two years later the company withdrew its requests because of ongoing global market rejection and pressure from farmers across North America who were concerned about the future of their wheat export markets.[267]

Although wheat is predominantly self-pollinating and GM wheat has never been commercially released, GM wheat contamination has already become an issue for growers in the US. In 2013, Monsanto's GM wheat was found growing in a field in the state of Oregon.[268] Japan, the US' largest export market for wheat, suspended imports of US wheat after the contamination was discovered.[269] The source of this contamination was not determined.[270] In 2014, GM wheat was also found growing on a former field trial site at a university research centre in Montana.[271]

Industry groups that support the commercialization of GM wheat are advocating for a policy called "Low Level Presence" (LLP),[272] which would mean that countries would accept some level of GM contamination in imports, even when the GM crop in question was not yet approved as safe by regulators in the importing country. *For more information see www.cban.ca/llp*

GM ALFALFA

GM alfalfa is grown in the US, but not yet in Canada. US plantings of GM glyphosate-tolerant alfalfa were first allowed in 2005, suspended until 2007, and then allowed again in 2011 after years of court challenges.[273]

The flow of genes and traits from GM to non-GM alfalfa is unavoidable. Farmers who grow alfalfa, use alfalfa products, or sell their alfalfa products to markets that have not approved GM alfalfa could be severely affected by this contamination. Even with limited plantings before 2007, the US has already seen contamination from GM alfalfa.[274]

In 2013, a Washington farmer's hay export was rejected because of GM alfalfa contamination.[275] The US Department of Agriculture did not investigate the source of this contamination, calling it a "commercial issue" that should be addressed by the marketplace, not by government.

Alfalfa is the first genetically modified perennial crop, and the biology and use patterns of alfalfa make it particularly susceptible to contamination through seed escape, cross-pollination, as well as through the emergence of volunteer and feral alfalfa.[276] Alfalfa seed is very small and the likelihood that seed may spill during planting, transport and harvest, or be spread by animals, is very high. Alfalfa is also an outcrossing plant that relies on insects for pollination. Furthermore, alfalfa survives well as feral populations in unmanaged habitats such as ditches, further exacerbating the risk of contamination from GM to non-GM fields.[277]

In 2013, the Canadian Seed Trade Association (CSTA) released what it called a "coexistence plan" for alfalfa hay in Eastern Canada.[278] The plan set out "best management practices" that the CSTA claimed would allow GM and non-GM alfalfa to coexist. However the plan was widely opposed by farmers in Canada[279] and described as "fiction".[280]

Alfalfa is a very important crop in farming systems across Canada. It is used as a high quality feed for livestock and to build soil fertility for growing other crops. Canada is among the top five global exporters of alfalfa products, which are used for animal feed in other countries. In Canada, contamination from GM alfalfa would come at a high price for organic and conventional farmers who do not wish to use or grow GM alfalfa, and to alfalfa product exporters. **The only way to prevent contamination from GM alfalfa is to stop its market release**.

In 2013, the National Farmers Union-Ontario called for a national Day of Action to Stop GM alfalfa that spurred rallies in 38 communities.[281] In 2015, the producer group Forage Seed Canada said that Canadian regulators had "failed to do a complete due diligence assessment in the approval of GE alfalfa for release into Canada, by neglecting to factor in potential market losses or market impact by allowing GE traits in alfalfa into Canada before widespread market acceptance."[282]

www.cban.ca/alfalfa

FOR MORE ON GM ALFALFA CONTAMINATION RISKS AND COSTS

- *Application for Review: Under Part IV, Environmental Bill of Rights, Ontario, Request for Environmental Assessment of Genetically Engineered Roundup Ready Alfalfa, "Question 4: A summary of the evidence that supports our Application for Review"* Submitted to the Environmental Commissioner of Ontario, July 2013.
- *The Canadian Seed Trade Association's so-called "Coexistence Plan" is a gateway to GM alfalfa contamination*. Canadian Biotechnology Action Network and National Farmers Union. July 2013.
- *The Inevitability of Contamination from GM Alfalfa Release in Ontario: The case for preventing the introduction of Roundup Ready alfalfa.* Canadian Biotechnology Action Network. April 2, 2013.

Few countries monitor and publicly record contamination or illegal releases of GMOs within their borders, or internationally. However, the European Union tracks and maintains a registry of all contamination incidents.[283] In 2005, a civil society initiative called the GM Contamination Register was set up by Greenpeace International and GeneWatch UK to compile all contamination incidents that have been publicly documented.[284] According to the register, **434 incidents of GM contamination have been recorded** as of July 2015.[285] These include illegal plantings, unintentional releases of GM seeds, and incidents where GM plants have crossed with wild and feral relatives.

A number of these GM contamination incidents have had very serious economic and social consequences. In 2000, for instance, GM "Starlink" corn, which was approved for animal feed but not human consumption, was found to have widely contaminated the food chain, in North America and internationally.[286] The USDA called for removal of the existing 350,000 acres of Starlink corn[287] and paid out between $172-million and $776-million to compensate producers.[288]

Contamination can have particularly profound consequences in areas that are centres of diversity or origin for particular crops. This was the case in Mexico, in 2000, when researchers found GM contamination of native Mexican corn (maize) landraces.[289] Indigenous and farming communities in Mexico have since called for a halt on GM corn imports and a continued moratorium on growing GM varieties.[290] The GM contamination resulted in unpredictable traits in corn plants for local farmers. According to Baldemar Mendoza, an indigenous farmer from Oaxaca, "We have seen many deformities in corn, but never like this. One deformed plant in Oaxaca that we saved tested positive for three different transgenes. The old people of the communities say they have never seen these kinds of deformities."[291]

GM contamination can and does occur even in cases of crops that have not been approved and/or commercialized. In 2006 and 2007, contamination from three varieties of Bayer's unapproved GM herbicide-tolerant "Liberty Link" rice was found in US export shipments and several countries closed their doors to US rice.[292] **Bayer eventually paid $750-million to resolve claims from about 11,000 U.S. farmers**.[293] GM rice, which has not been commercialized anywhere in the world, accounts for a third of all contamination incidents.[294] Corn accounts for another 25% of GM contamination incidents, and soy and canola another 10%.

Human error, crop biology, pollinator and wind movement, and other factors make contamination incidents inevitable, and it is very difficult to predict exactly when and how particular transgenes will escape, and how they will then spread and interact with the environment. Once GM contamination takes place, it is difficult or impossible to reverse. **Experience shows that the only way to prevent contamination from GM crops is to not release GM crops into the environment**.

CONCLUSION

The high level of corporate consolidation in the seed market has been partly facilitated by the use of GM technology. This corporate concentration has meant that seed prices have risen at a faster rate than other farm inputs, while farm incomes in Canada have not increased. The choices available to farmers in the market have decreased, and legal control, in the form of patents that prevent farmers from reusing seed, has increased.

Farmers have not yet benefitted from increased yields or rising net incomes because of GM traits. The benefits that GM herbicide-tolerant crops may have offered farmers are now being reversed due to the new management costs of herbicide-resistant weeds.

In Canada, there is no assessment of the potential economic consequences of introducing new GM crops. For example, potential GM contamination is only assessed in relation to a narrow set of questions about environmental impacts, not in relation to potential economic costs, despite the fact that farmers can pay a high price. Farmers in Canada are not consulted before genetically modified crops are approved, for field trials or commercial release.

Twenty years of GM crops have benefitted the companies that sell GM seeds, but have not always benefitted farmers.

> "Farmer experiences regarding this technology have yet to be fully studied for Canada, the United States, and Argentina as the first countries to commercialize GM crops, or are restricted to the benefits. The role and potential contribution of farmer knowledge also has yet to be systematically evaluated for any GM crops and, indeed, risk research as a whole[295]
>
> — Mauro and McLachlan, 2008

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