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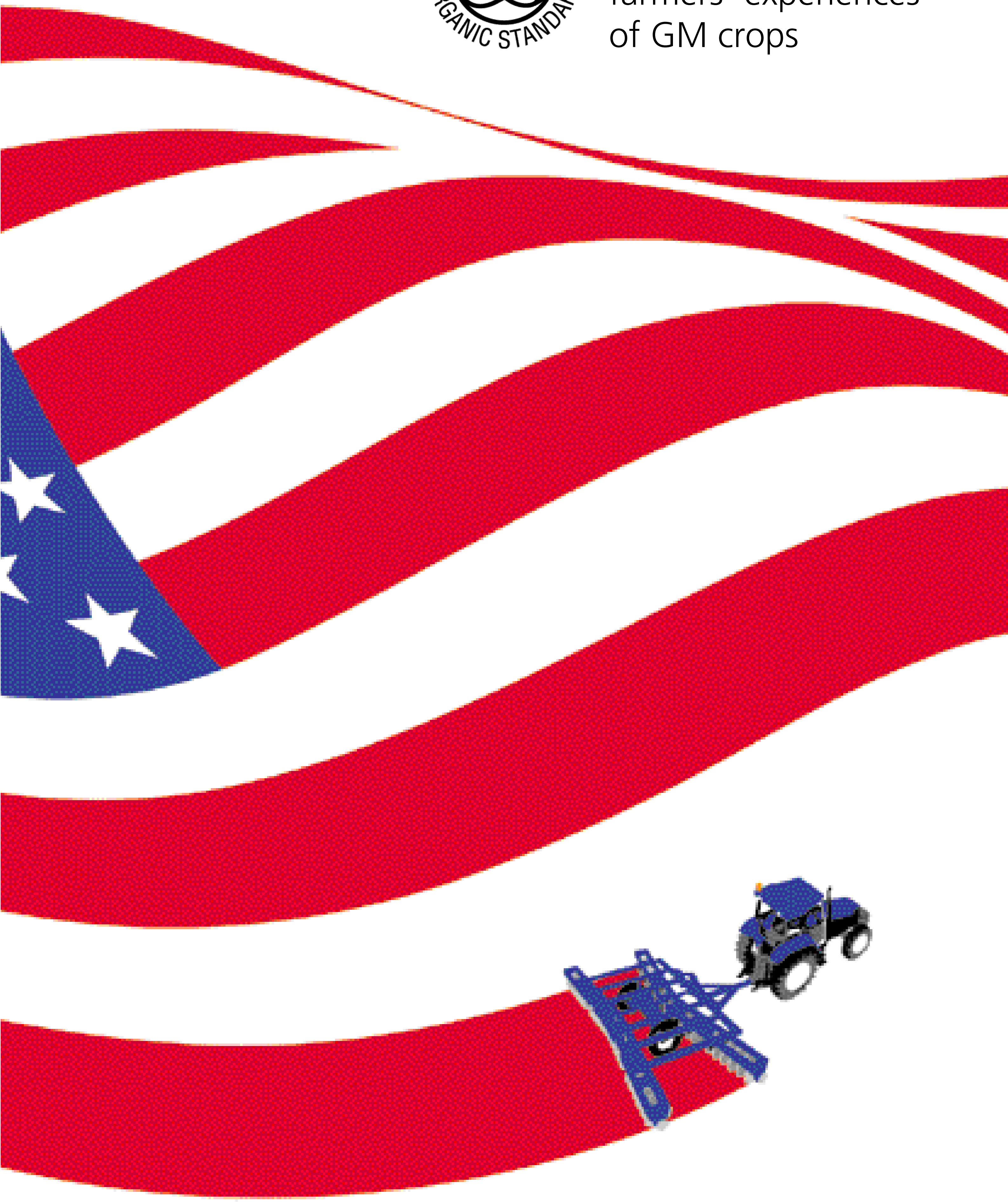
Seeds of doubt

North American farmers' experiences of GM crops



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Preface

Perhaps the greatest achievement of the biotechnology industry has been in creating a myth and then transforming it into a political orthodoxy. It has managed to persuade some of the world's most powerful governments that the 'white heat of biotechnology' can bring benefits of higher yields, lower chemical use, food security and, critically, profitability for farmers.

Those who have signed up seem enthralled by the apparent potential of genetic engineering to improve on nature. Yet, despite growing public alarm (generally dismissed as irrational fears born of scare mongering) the accuracy of these claims have not, until now, been put under the microscope.

In undertaking this study of the actual impact of the commercialisation of GM crops in North America, the Soil Association has gathered sufficient evidence to challenge the fundamental proposition that GM technology represents progress.

The evidence we set out suggests that, in reality, virtually every benefit claimed for GM crops has not occurred. Instead, farmers are reporting lower yields, continuing dependency on herbicides and pesticides, loss of access to markets and, critically, reduced profitability leaving food production even more vulnerable to the interests of the biotechnology companies and in need of subsidies.

The report makes disturbing reading, but at a time when a decision has to be made in the national interest about the commercial introduction of GM crops, we hope it will result in a better informed public debate – and a more independent, less pressurised decision.

Patrick Holden
Director, Soil Association

Executive summary

The UK government and farming community will soon make a fundamental and long-term decision: whether to allow genetically modified (GM) crops to be commercially grown in the UK. The picture the biotechnology industry has painted of GM crops in North America is one of unqualified success, after six years of commercial growing. The objective of this report was to assess whether this image is accurate and if not what problems have occurred. We present interviews with North American farmers about their experiences of GM soya, maize and oilseed rape, and review of some of the independent research.

The evidence we have gathered demonstrates that GM food crops are far from a success story. In complete contrast to the impression given by the biotechnology industry, it is clear that they have not realised most of the claimed benefits and have been a practical and economic disaster. Widespread GM contamination has severely disrupted GM-free production including organic farming, destroyed trade and undermined the competitiveness of North American agriculture overall. GM crops have also increased the reliance of farmers on herbicides and led to many legal problems.

Six years after the first commercial growing of GM crops, the use of genetic engineering in global agriculture is still limited. Only four countries including the US and Canada grow 99 per cent of the GM crops grown worldwide, and just four crops account for 99 per cent of the global area planted to GM crops. In the UK, we have a choice over whether to remain GM-free.

Our findings show that GM crops would obstruct the government from meeting its policy objective that farming should become more competitive and meet consumer requirements. It would also prevent it from honouring its public commitment to ensure that the expansion of organic farming is not undermined by the introduction of GM crops. The Soil Association believes this report will contribute towards a more balanced and realistic debate on the likely impacts of GM crops on farming in the UK and assist an informed decision on the commercialisation of GM crops.

Farming impacts

The direct impacts of GM crops on farmers in North America are examined in chapters 3–6, 8 and 9. Many of the claimed benefits have not been seen in practice and several unforeseen problems have emerged:

- The profitability of growing GM herbicide tolerant soya and insect resistant Bt maize is less than non-GM crops, due to the extra cost of GM seed and because lower market prices are paid for GM crops
- The claims of increased yields have not been realised overall except for a small increase in Bt maize yields. Moreover, the main GM variety (Roundup Ready soya) yields 6–11 per cent less than non-GM varieties
- GM herbicide tolerant crops have made farmers more reliant on herbicides and new weed problems have emerged. Farmers are applying herbicides several times, contrary to the claim that only one application would be needed. Rogue GM oilseed rape plants (‘volunteers’) have become a widespread problem in Canada
- Farmers have suffered a severe reduction in choice about how they farm as a result of the introduction of GM crops. Some are finding themselves locked into growing GM crops.

Contamination

In chapter 7 we look at GM contamination, which has been the single greatest problem. Widespread GM contamination has occurred rapidly and caused major disruption at all levels of the agricultural industry, for seed resources, crop production, food processing and bulk commodity trading. It has undermined the viability of the whole North American farming industry:

- Contamination has caused the loss of nearly the whole organic oilseed rape sector in the province of Saskatchewan, at a potential cost of millions of dollars. Organic farmers are struggling practically and economically; many have been unable to sell their produce as organic due to contamination

- All non-GM farmers are finding it very hard or impossible to grow GM-free crops. Seeds have become almost completely contaminated with GMOs, good non-GM varieties have become hard to buy, and there is a high risk of crop contamination
- Because of the lack of segregation, the whole food processing and distribution system has become vulnerable to costly and disruptive contamination incidents. In September 2000, just one per cent of unapproved GM maize contaminated almost half the national maize supply and cost the company, Aventis, up to $1 billion.
- One of the most unpleasant outcomes of the introduction of GM crops has been the accusations of farmers infringing company patent rights. A non-GM farmer whose crop was contaminated by GMOs was sued by Monsanto for $400,000
- While biotechnology companies are suing farmers, farmers themselves are turning to the courts for compensation from the companies for lost income and markets as a result of contamination. In Canada, a class action has been launched on behalf of the whole organic sector in Saskatchewan for the loss of the organic rape market.

Economic impacts

The economic impact of GM crops is the focus of chapter 10. GM crops have been an economic disaster. As well as the lower farm profitability, GM crops have been a market failure internationally. Because of the lack of segregation, they have caused the collapse of entire exports to Europe and a loss of trade with Asia:

- Within a few years of the introduction of GM crops, almost the entire $300 million annual US maize exports to the EU and the $300 million annual Canadian rape exports to the EU had disappeared, and the US share of the world soya market had decreased
- US farm subsidies were meant to have fallen over the last few years. Instead they rose dramatically, paralleling the growth in the area of GM crops. The lost export trade as a result of GM crops is thought to have caused a fall in farm prices and hence a need for increased government subsidies, estimated at an extra $3–$5 billion annually
- In total GM crops may have cost the US economy at least $12 billion net from 1999 to 2001.

Legal issues

GM contamination has led to a proliferation of lawsuits and the emergence of complex legal issues (chapter 11):

Farmers' response

The severe market problems have led many North American farmers to seriously question the further development of GM crops (chapters 10 and 11):

- Many US farm organisations have been urging farmers to plant non-GM crops this year
- The US and Canadian National Farmers Unions, American Corn Growers Association, Canadian Wheat Board, organic farming groups and more than 200 other groups are lobbying for a ban or moratorium on the introduction of the next major proposed GM food crop, GM wheat
- With the support of several farming organisations, federal legislation was tabled in Congress in May 2002, to introduce GM labelling and liability rules in the US.


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1 Introduction

The government and UK farming community will soon be taking a decision of fundamental and long-term importance for UK agriculture: whether or not to allow genetically modified (GM) crops to be grown commercially in this country. Currently the UK is among the vast majority of countries in the world where there is no commercial growing of GM crops, and also no market demand. However, this de facto moratorium is set to end with the completion of the government's programme of farm GM trials next spring and following a proposed public debate. Were GM crops to be given the green light and there to be a market, commercial planting could begin as early as autumn 2003.

In September 2001, the Agriculture and Environment Biotechnology Commission (AEBC), the government's independent advisory body on biotechnology and agriculture, published its report, *Crops on Trial*. This said that the GM trials programme alone would not provide enough information for the government to allow commercial growing of GM crops and a decision should only be taken after an independent review of the evidence from those countries where GM crops are already commercially grown. The AEBC also proposed that there should be a broader public debate on GM crops. The Soil Association welcomed this announcement and trusts this report will be a helpful contribution to this debate.

This report reveals the experiences North American farmers have had of growing GM crops and the impacts these crops have had on their industry. Four GM crops have been grown commercially on a large scale for the last six years in the US and Canada. The biotechnology industry has portrayed this experience as successful, suggesting the crops are popular and bring significant benefits to farmers. There has been little questioning of this picture, and it has added to the already substantial pressure for the introduction of GM crops here. In the face of these widely reported industry claims of total success, we set out to see if in fact there were any problems and if so what they were.

To our amazement, the feedback from farmers and industry analysts in North America is that across the whole industry there have been more problems than successes. There have been some beneficial aspects, but a large number of serious problems. Unless these experiences are properly considered, there is a real danger that the forthcoming decision in the UK will be taken on a misleadingly narrow and theoretical basis.

The three year programme of farm-scale GM trials has been repeatedly presented by the government and biotechnology industry as the cornerstone for the decision on GM crops. The AEBC has been critical of this, stressing that there are many important questions that the trials will not answer. The trials have always had a very narrow remit. They are investigating only the short-term impact of the management regime of one group of GM crops, herbicide tolerant GM crops, on farmland biodiversity. They will reveal little about the environmental or wider impacts of GMOs, nor about the impact on farmers and the agricultural industry, and the results will only be applicable to those particular crops and not to commercial growing involving continuous use of one or more GM crops.

Concerns about GMOs have been voiced mainly by the general public and environmental organisations. The major food retailers and manufacturers in the UK have responded by adopting GM-free sourcing policies. In contrast, the apparent interest from the farming industry has probably provided the only real support for the government's wish to proceed down the GM path, apart from the biotechnology sector itself. However, individual farmers who would be the clients of this technology and at the forefront of any negative impacts, have received little information about the implications of GM crops, other than from the biotechnology companies. While there is as yet little data on the potential environmental and health risks, there is now plenty of information on the impact of GM crops on farmers across the Atlantic.

It is important that the UK farming community takes this opportunity to learn the lessons from those who have already tried these crops on a large scale. With UK agriculture still suffering a deep economic crisis, the temptation to seize a new technology is great. But in North America, farmer ignorance was one of the biotechnology industry's greatest marketing assets – it explains to a large extent how GM crops were introduced there in the first place.

The Soil Association has a particular interest in the impacts of GM crops. The organisation exists to promote sustainable, healthy food production and is the main certifier and promoter of organic food and farming in the UK. To ensure sustainable and healthy food production, the principles of organic agriculture centre on the need for farming practices to be based on natural biological processes and a precautionary approach to safety issues. On this basis, the International Federation of Organic Agriculture Movements (IFOAM), with the full support of the Soil Association, agreed in 1994 that there is no place for GM technology in organic agriculture. Organic production standards worldwide now prohibit the use of GMOs by law. The fact that organic food is GM-free is one of the key reasons for the consumer demand for organic food in the UK.

The organic food sector offers farmers a major and growing high value market. The retail market is now worth about £920 million in the UK and was £15 billion worldwide in 2000,[1] several times larger than the global market for GM seeds estimated at $3.7 billion (the only relevant market is for GM seed; there is no specific demand for GM food).[2] The government is increasingly recognising the economic and environmental opportunities of organic farming and is investing in its development. However, the real danger remains that, should GM crops be commercialised, they could severely damage the sector's future. The Soil Association has expressed concern for many years that GM contamination could disrupt the ability of farmers to supply the organic market and consumers to buy UK organic food. But this problem is not special to the organic sector. As long as the public want a choice of GM-free food and clear labelling of GM products, GM crops have the potential to disrupt the non-organic farming sector as well.

This report will help farmers and farm policy officials to weigh up the merits and drawbacks of GM crops. It looks at the three main GM crops being grown in North America which could also be grown in the UK: soya, maize and oilseed rape. Through a review of some of the academic evidence and farmers' own experiences, it sets out the agronomic, economic and legal impacts on farmers. It examines the immediate impact of GM crops on yield, agrochemical use, and farmer income. It looks at the indirect impacts such as the development of herbicide resistant volunteer plants, contamination, farmer choice and the legal consequences for farmers. It also examines the wider impacts on trade and the farming economy.

2 Context

GM crops around the world

GM crops were first grown commercially in 1996 in the US, but, six years later, most countries are still not growing GM crops. Four countries account for 99 per cent of the total area of GM crops, and they include the US and Canada. The global area stood at 52.6 million hectares in 2001.

The main GM growing countries[1]

Country	*Total area GM in 2001 (million ha)*	*% of global GM crop area in 2001*
USA	35.7	68%
Argentina	11.8	22%
Canada	3.2	6%
China	1.5	3%

The key GM crops and companies

Four main GM crops are being grown commercially: soya, cotton, oilseed rape and maize. They account for 99 per cent of the total global GM acreage.[2] However, only 19 per cent of the global area planted to these crops in 2001 was GM. Three of these GM crops could be grown in the UK: soya, rape and maize; all are used principally for animal feed and vegetable oils and soya is used in a wide range of processed food.

The main GM crops[1]

Crop	*Total area planted 2001 (million ha)*	*% of total area that is GM*
Soya	72	46%
Cotton	34	20%
Oilseed rape	25	11%
Maize	140	7%

These crops have been engineered with just two traits. One set of GM crops are resistant to particular herbicides so that the herbicides can still be applied to the field while the crop plants are growing, for example Roundup Ready (RR) soya, oilseed rape and maize. The other set produce an insecticide, the toxin from the bacteria *Bacillus thuringiensis*, to make the crop, such as Bt maize, resistant to insect attack.

Four companies produce almost all of these four crops. The US company Monsanto dominates the market: in 2000 they accounted for 91 per cent of the total GM area. Syngenta (formerly Novartis/AstraZeneca), Aventis CropScience (formerly AgrEvo, now acquired by Bayer) and Dupont account for virtually all the remaining commercial plantings of GM crops.[2] It is estimated that the global market for GM seeds totalled $3.67 billion last year.[3]

GM crops in the US and Canada

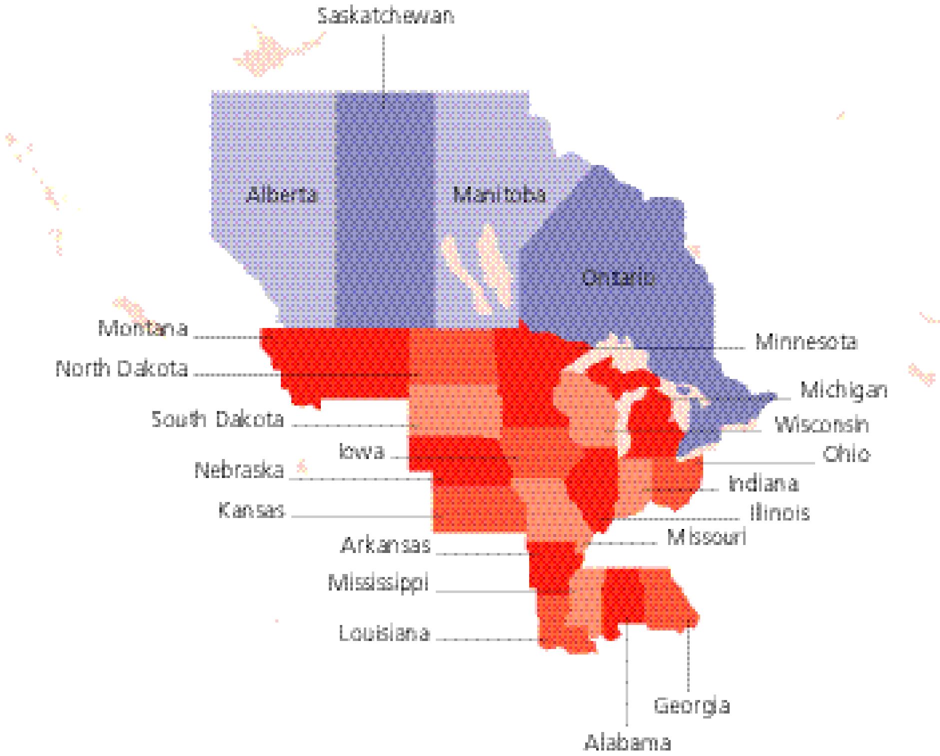
In the US, the principal soya states are: Alabama, Arkansas, North Dakota, South Dakota, Georgia, Illinois, Indiana, Iowa, Louisiana, Minnesota, Mississippi, Missouri, Nebraska and Ohio.[4] Of the three main GM feed crops, the GM soya hectarage grew most rapidly and was about 65 per cent of the total soya area in 2001.

The principal maize growing states are: South Dakota, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio and Wisconsin.[4] According to a survey carried out for the American Corn Growers Association of 509 maize producers, the percentage of the total maize area planted to GM maize in 2001 was 21 per cent (+/-4.5 per cent).[5]

Oilseed rape has only been approved for growing in two US states since 2001. In Canada, oilseed rape is the main GM crop grown on the prairies. Approximately, 60 per cent of the rape there is GM.[6] Maize and soya in Canada are primarily grown in Ontario.[7]

GM policies of UK retailers

All of the major UK food retailers have GM-free policies for their own brand products. The Co-op, Iceland, Marks and Spencer, Safeway, Sainsbury, Tesco and Waitrose have all made statements confirming this position.[8] They are all also in the process of introducing GM-free animal feed policies for their meat and dairy products. For example Sainsbury "is committed to the removal of GM from animal feed," the Co-op is trying to ensure that "no Co-op brand product is derived from animals fed upon a diet containing GM crops" and Safeways informed its



Provinces and states where GM soya, maize and oilseed are grown

suppliers that it wished "to achieve non-GM status for animal feed as soon as possible."[9]

The organic food and farming sector

The global organic food market has being growing rapidly over the last few years and stood at £15 billion in 2000. The US has the largest organic market at almost £5 billion in 2000 and has been reporting annual growth of over 20 per cent The area of organic farmland, however, was only 0.22 per cent of total US farmland. The Canadian organic sector is comparatively underdeveloped, with only 188,000 ha being farmed organically in 2000 and a small organic food market.

The UK has the fastest growing and most import dependent organic market in Europe, with a retail value of about £1 billion in the year to April 2002. The area of organically managed land stood at 3.2 per cent of total UK farmland in 2001, slightly over the EU average of nearly three per cent in 2001. This was farmed by 3,700 producers. The government is investing in the growth of the organic sector and one of its "public service agreements" is an increase in the area of organic farming.[10]

Research for the report

In January and February 2002, one of the authors of this report travelled around the Midwest of the United States interviewing farmers who have been affected by the commercial growing of GM crops. These included farmers who had grown GM crops as well as organic farmers whose livelihoods were threatened by neighbouring GM crops. Literature research was also undertaken – focusing on the data and analysis of independent US and Canadian experts and government bodies, rather than that supplied by the biotechnology industry.

"The application of biotechnology at present is most likely… not to increase maximum yields. More fundamental scientific breakthroughs are necessary if yields are to increase."
USDA, 2001 Agriculture Information Bulletin[1]

3 Yield

GM crops were marketed on the promise of significant yield increases. For example, an advert for Monsanto's Asgrow soya in 2002 stated: "Asgrow varieties return more and yield higher because they're driven by progress,"[2] and in relation to Roundup Ready maize the company claimed "outstanding yields."[3] After six years of commercial production, there is only a limited amount of independent information for farmers on the actual yield performance and other impacts of GM crops. Nevertheless, the information available generally indicates that the outcome has been very different to the claims made by the biotechnology industry.

Analyses of several years of data by a few independent researchers and the Economic Research Service of the United States Department of Agriculture (USDA) show that, for soya, maize, and rape, they have mostly failed to live up to the claims. The results differ between crop and region, and also from year to year. Overall, yields are lower for Roundup Ready (RR) soya and apparently also RR rape, and have increased for only one crop, Bt maize, and then by only a small amount which was not enough to cover the extra production costs. Though there is some information on yield for all GM crops, the most solid evidence available is for RR soya.

RR soya

A poll of 800 Iowa farmers by Iowa State University revealed that the principal reason why farmers chose to plant RR soya (53 per cent) was because they thought it increased yields.[4] However, RR soya stands out as the GM crop that has failed most obviously, with both the research data from US and Canada and farmers' personal accounts testifying to significant yield decreases.

Researchers from the University of Nebraska conducted a controlled field experiment at four locations over two years to evaluate the effect that genetically engineered glyphosate resistance had on soya yield. They compared five Roundup Ready varieties with near isogenic lines – that is crops where the only difference between the GM and non-GM varieties was the genetic modification. They also compared them with high-yielding non-GM soya varieties. In a paper published in *Agronomy Journal* in 2001, they concluded that genetically engineered soya yielded six per cent less than non-GM 'sister lines' and 11 per cent less than high yielding non-GM soya.[5] Importantly, this study is one of the only side by side controlled trials comparing GM crop yields with their identical non-GM varieties; it is also one of the few peer reviewed, published studies on GM yields. It is supported by other research.

In 1999 and 2000, over 10,000 comparative RR versus conventional soya varietal trials were carried out across the US, including a series of independent university trials. Dr Charles Benbrook, an independent agronomy consultant in Idaho, has analysed this data and found that the results are fairly consistent. They show that RR soya produces a yield decline of five per cent to 10 per cent in most circumstances.[6]

Benbrook also took a cross section of the university trial results from three US states and found that comparisons with the top performing conventional varieties provide some even worse results. In Indiana, the top RR variety offered by three seed companies yielded on average 15.5 per cent less than the top conventional variety; in Iowa the reduction was 19 per cent; and in Illinois the reduction was less than one per cent.[6]

This is confirmed by feedback from

Newell Simrall

Monsanto subsidiary Jacob Hartz Seed Company claimed that their Roundup Ready soya seeds were "top quality, disease resistant, high yielding seeds." But the Mississippi state court ruled in September 2001 that they were responsible for the reduced yields obtained by Mississippi farmer Newell Simrall, and confirmed the award of $165,742 in damages to him.[20, 21]

the industry. For example, Canadian soya merchant Gerald Fowler said in 1999 that the reduction is "about 10 per cent quoted by most [farmers] in this area."[7]

These results stand in stark contrast to the claims made by the biotechnology companies. Monsanto literature in 1998 stated that they had achieved an average five percent increase in yields with their RR soya.[8]

Bt maize

In a summary of the studies of various researchers the USDA determined that Bt maize produced higher yields, "in most years and some regions."[9] In a later study Dr Benbrook concluded that Bt maize had resulted in a small yield increase of around 3.9 bushel/acre.[10] The average yield in 2000 was 148 bushel/acre,[11] so this represents an increase of around 2.6 per cent.

HT maize

In 2001, the USDA stated, "adopting herbicide tolerant corn did not increase yields."[1] Again, this contrasts with the impression given by the advertising: "Outstanding yields and reduced input costs… the Roundup Ready corn system costs less, while allowing hybrids to reach their maximum yield potential."[3]

RR rape

A study by University of Saskatchewan researchers published in 1999 revealed that the yields of Roundup Ready oilseed rape fell around 7.5 per cent short of conventional rape. The RR rape managed 33 bushel/acre while the conventional achieved 35.7 bushel/acre.[12]

Backtracking on claims

Many industry supporters have now started to backtrack from the earlier claims about higher yields. In 1999, USDA did a general assessment of the performance of GM crops in 1997 and 1998, including GM cotton, looking at data for the different crops and regions. At the time they concluded that in two thirds of cases, 12 out of 18 crop/region combinations, there were no significant differences in yield between GM and non-

Michael Alberts

Michael Alberts, from Marquette, Nebraska, farms just over 1,000 acres of land, mainly growing maize and soya. He was interested in using Roundup Ready soya as a way of keeping his fields clean but was disappointed to find that "Roundup Ready beans do not yield as well as conventional beans. The conventional beans harvested about 20 bushels/acre more than the Roundup Ready beans."[19]

George Holkup

George Holkup from Wilton, North Dakota was thinking of buying Roundup Ready maize last year, but he was talked out of it by the seed salesman. He was told that it wouldn't canopy and that it was yielding 10–15 bushels/acre less.[22]

GM crops, while in a third of cases GM yield were higher.[13] By 2001, they had concluded that biotechnology was most likely "not to increase maximum yields. More fundamental scientific breakthroughs are necessary if yields are to increase."[1]

Why claims have not been realised

No commercial GM variety has yet been engineered specifically to have a higher physiological yield potential; the focus of genetic engineers so far has been weed and pest management. For this reason, all cases where farmers have experienced increased yields have been as a result of reduced crop damage from pests or reduced weed competition. This also means that yield increases only occur if the control achieved with the GM crop is needed and is greater than would be obtained with conventional methods.[14] In the case of Bt crops, as corn borer attacks are episodic and not always a problem, there is only a yield gain in those regions and seasons where and when pest levels are significant.[15]

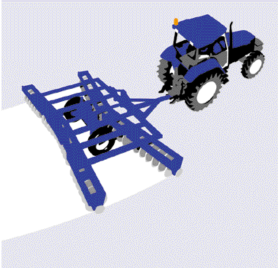
The yield reductions in RR soya seem to result from three specific problems: the use of lower yielding varieties by the breeders, a negative side effect of the genetic engineering process, and a negative side effect of the glyphosate herbicide that is applied to the plants.

The University of Nebraska study concluded that the 11 per cent reduction in RR soya yields was due to two factors. There was a six per cent reduction due to an unintended side effect of the genetic engineering, either related to the gene or to the insertion process. Clearly, this effect had either not been identified prior to commercialisation or had not been publicised. The other five per cent reduction in yield was due to the fact that the GM varieties were based on lower yielding cultivars.[5]

The genetic engineering of RR soya seems to have had a negative side effect on the plant's ability to deal with stress, such as excessive cold or heat, or a mineral or microbial imbalance in the soil. These problems are believed to have arisen because the genetic material that is randomly inserted into RR crops to make them tolerant to the herbicide has also altered the functioning of other biochemical pathways which control the plants' stress responses. The result of this, concluded Dr Benbrook, in a statement in 2002 is

3. Key points

- ★ The main reason farmers say they chose GM crops was for increased yields
- ★ On average, the claims of increased yield have not been realised for most GM crops; some have reduced yields
- ★ RR soya yields six per cent less than otherwise identical non-GM varieties and 11 per cent less than high-yielding non-GM soya varieties. This is thought to be partly due to a side effect of the genetic engineering process
- ★ RR rape yields less than non-GM rape
- ★ HT maize has not produced higher yields
- ★ Bt maize produced a yield increase of about 2.6 per cent, which was not enough to offset the higher production costs.



that, "It now appears that RR crops are more vulnerable to certain diseases and insect pests under some relatively common circumstances, which will in the long run either increase the use of other pesticides or decrease yields."[16]

Research published by University of Arkansas scientists in 2000 revealed another unintended side effect: the glyphosate herbicide disrupts the nitrogen fixation process in RR soya. Root development, nodulation and nitrogen fixation were found to be impaired in some RR varieties, and this is exacerbated in dry or low fertility conditions. According to the study, this is caused by sensitivity of the bacteria that fix the nitrogen, *Bradyrhizobium japonicum*, to Roundup.[17] The data revealed that the effect of the delay and decrease in nitrogen fixation means yields can be down by up to 25 per cent.[16] Unfortunately, this information was only available after 100 million acres of RR soya had already been planted in America.

The poor overall yield performance of most GM varieties may be due to a general problem with GM crops. The task that the new gene performs requires additional energy which will detract from the plant's capacity to grow normally.[15]

Where an increase in yields has been reported for a GM variety, it could be due to reasons which are not related to the GM trait. Higher yields may simply be due to the fact that a higher yielding hybrid has been used by the biotechnology companies, rather than necessarily due to the genetic modification; in other words it would have been higher yielding even were it issued as a non-GM variety.[18]

Yield information from farmers will be affected by the availability of different varieties on the market. Farmers in North America have reported that over the last few years, as the GM varieties were introduced, the availability of good non-GM varieties on the market has been significantly reduced.[19] This will to some extent be obscuring the comparative performance of GM and non-GM crops on the ground in favour of GM crops.

There is a final problem with the yields from GM crops. GM varieties increase farmer seed costs by 25 per cent to 40 per cent an acre, so yields have to be higher and/or other costs lower for farmers to break even. Thus, even where the data shows that yields have increased for some farmers, the increase may not be sufficient to avoid the farmers being worse off financially. For example, although US farmers who planted Bt maize harvested on average 3.9 more bushels/acre over the last six years, this still did not cover the extra costs of growing the GM crop. Yield would have had to rise by over another bushel an acre to cover the higher production costs.[10]

"In most regions where Roundup Ready beans have been planted for more than three years, herbicide reliance continues to increase as a result of the combination of weed shifts and resistances."
Dr Charles Benbrook, agronomist, Idaho, 2000[1]

4 Agrochemical use

Bill Christison

Bill Christison is president of the US National Family Farm Coalition. When growing conventional soya, he uses 10 to 12 ounces of chemicals an acre. But he has seen what farmers who are growing Roundup Ready soya are doing. First they spray to clear the ground of weeds before planting, then when the beans emerge, weeds also appear so there needs to be reapplication of Roundup. "Most farmers have found that they should also use a residual herbicide to help kill the weeds because the weeds have become somewhat resistant to Roundup," he explained. "The upshot is that you could easily use 60 to 75 ounces of chemical per acre. What you have is a yield loss and a huge amount more chemical being applied per acre."[2]

Proponents of biotechnology have long claimed that GM herbicide tolerant (HT) and Bt crops would significantly reduce agrochemical use and simplify weed and pest management. They also claimed they would reduce the use of older, more toxic herbicides. These claims were the centrepiece of Monsanto's marketing strategy in 1998 and they have been the main reason put forward by the biotechnology industry for the argument that GM crops could be environmentally beneficial.

However, independent analysis of four years of USDA data indicates that, contrary to the claims, more herbicide and insecticide is being used with HT crops and Bt maize. Some of the benefits have turned out to be short-lived because the intended weed control strategy affected yields and because new weed and volunteer problems have emerged as a result of HT crops. There are indications that the use of GM crops is resulting in a reversion to the use of older, more toxic compounds.

The main reason why GM crops have been popular with farmers has been the attraction of the convenience of herbicide tolerant and insect resistant crops, and the fact that the greater freedom of herbicide use enables more weed control. However, this is being undermined by the emergence of several new weed problems and the need for farmers to take special measures against the development of insect resistance.

4.1 Herbicides

Two herbicide tolerant (HT) GM crops are grown commercially in North America. Roundup Ready crops have been engineered to be resistant to Monsanto's herbicide Roundup, a brand name for the chemical glyphosate. Similarly, though not grown on the same scale, Liberty Link crops are resistant to Aventis' herbicide Liberty, the brand name for glufosinate. The biotechnology companies had claimed that they would require only one application of herbicide.

However, unforeseen problems have meant that herbicide use has not decreased in the way intended. According to independent analyst Dr Benbrook, US government statistics confirm that GM HT crops increased the average amount of herbicide applied to the land.[3]

RR soya

One study of crop data from 172 fields in Iowa concluded that herbicide applications were less frequent on RR soya.[4] However, from USDA data for 1998, Dr Benbrook, concluded that RR soya requires "more herbicides than conventional soybeans, despite claims to the contrary. This conclusion is firmly supported by unbiased field-level comparisons of the total pounds of herbicide active ingredient applied on an average acre of RR soybeans in contrast to conventional soybeans."[5] Comparisons with the extremes of herbicide use were particularly dramatic. Benbrook's analysis revealed that the 10 per cent most heavily treated fields (predominantly RR) required at least 34 times more herbicide than the bottom 10 per cent (planted to non-GM varieties).[5]

By 2001, Benbrook was able to draw on four years of USDA data and concluded that modestly more pounds of herbicides are applied to the average acre of RR soya compared to non-GM soya, and that herbicide use on RR soya is gradually rising.

Glyphosate

Glyphosate herbicides are marketed as benign. They certainly are an improvement over older, more toxic chemicals, but when Monsanto went as far as advertising Roundup as 'biodegradable' and 'environmentally friendly', the New York State attorney general successfully challenged them. Monsanto was required to stop using these descriptions and had to pay $50,000 towards the legal fees.[11]

There is a strong body of independent research that glyphosate, an organophosphorous compound, is harmful. A Californian study showed that it was the third most frequent cause of illness amongst agricultural workers.[12] Harmful effects recorded have included eczema and respiratory problems.[13] It has toxic effects on some beneficial soil organisms, including negative effects on nitrogen-fixing bacteria in legumes, and it increases crop susceptibility to disease. It is very mobile and can leach easily, and can remain active in the soil for over four months. Many of the formulations are acutely toxic to fish.[12]

Glufosinate

Glufosinate is highly soluble and classed as persistent and mobile by the US Environmental Protection Agency. It is toxic to beneficial soil organisms and some aquatic organisms.[14]

In addition, "Average per acre pounds of herbicide applied on RR soybeans exceeds by two to 10-fold herbicide use on the approximate 30 per cent of soybean acres where farmers depend largely on low-dose imidazolinone and sulfonylurea herbicides."[3]

Indeed, as early as 1997 it was evident that the claims that RR soya would require no more than one application were foundering. An Iowa State University scientist revealed to a British crop protection conference that, while in 1996 a single application of herbicide had been used for RR soya, in 1997, planting conditions were different and unless alternative weed management was included, a second, or even third application was necessary.[6]

This contrasts with Monsanto's claims that "herbicide use was, on average, lower in Roundup Ready soyabean fields than in other US soyabean fields" and that a reduction of 22 per cent was to be expected.[7]

RR maize

According to Dr Benbrook, USDA data also revealed that, in 2000, RR maize was treated with about 30 per cent more herbicide on average than non-GM maize.[3]

Liberty Link maize

Maize growers have found that Liberty Link does not achieve adequate weed control without repeated applications of glufosinate. A majority are therefore now using the more toxic, persistent herbicide atrazine in addition to glufosinate, according to Dr Mike Owen of Iowa State University. Aventis/Bayer had claimed that one of the main benefits of the GM maize would be the substitution of atrazine with glufosinate.[8]

HT rape

A survey of crop management practices of 650 oilseed rape growers in Canada of the 1997 to 2000 crop, carried out by the Canadian canola industry, found HT rape had been treated on average about 20 per cent more often than non-GM crops, with 2.1 herbicide applications to Roundup Ready and Liberty Link crops compared to 1.8 applications to non-GM crops.[9] Though farmers may reduce their use in the first year, they are using more in the following years to control volunteer GM rape.[10]

Why herbicide use has not gone down

Increases in herbicide use were probably to be expected with HT crops. Both glyphosate and glufosinate are broad spectrum herbicides that are toxic to most plants including normal crop plants, so they normally cannot be applied to a field once the crop has grown. GM herbicide tolerant technology means that farmers can now use these chemicals during the growing period. Farmers are generally keen to eliminate as many weeds as possible and often aim for completely 'clean' fields, even if complete weed control is not necessary or advisable in overall economic terms. HT crops enable farmers to achieve this aim. For example, easier and better weed control was the top reason given by western Canadian growers for chosing HT rape.[9] While HT crops are therefore a very easy and attractive option for farmers, they set agriculture back on a more chemical dependent path.

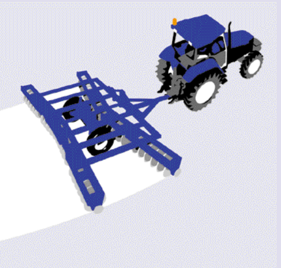
The claim that GM crops would result in lower agrochemical use was based on the flexibility of being able to use the herbicide at any time. This meant that it could then be applied at the most effective time for weed control, and thus require only one application. However, farmers have found that, for a single application to be sufficient for weed control purposes, it needs to be applied at a late stage in crop development, by which time the weeds have been present most of the time and caused a yield loss. In practice, most farmers are therefore applying herbicides several times throughout the life cycle of the HT crop.[6] This could be anything up to six applications of glyphosate in total.[15] Many farmers are also still using other herbicides as well as glyphosate and glufosinate, such as applying persistent herbicides before the crop emerges that will have a continuous effect.[16]

This intense use of glyphosate is leading to new weed control problems which are gradually offsetting the convenience of HT crops. Different weed species are not equally susceptible and shifts are occurring in the composition of the weeds in the fields, towards species that are less affected by the herbicide.[3] In most states with a substantial RR soya acreage, there is also now evidence of weed species developing resistance to glyphosate.[17] These weeds are requiring much heavier applications of herbicides.

The experience in Iowa shows that shifts in weed populations can happen very rapidly. For example, common waterhemp (*Amaranthus rudis*) populations delayed germination and escaped the glyphosate applications. Already in 1997, velvetleaf

4.1 Key points

- ★ Herbicide tolerant (HT) crops have been widely adopted as they have reduced the normal constraints on herbicide use
- ★ The claim by the biotechnology companies that HT crops would only require one herbicide application and so reduce agrochemical use has not been realised in practice
- ★ RR soya, RR maize and HT rape appear to be resulting in a greater use and reliance on herbicides particularly after a few years
- ★ A single application has turned out to be impractical as it affected yields; instead farmers are applying herbicide several times in the pursuit of completely 'clean' fields, or applying older and more toxic herbicides in addition
- ★ New weed problems have emerged with HT crops which are leading to a greater need for herbicides
- ★ These include the appearance of more weed species which are less affected by herbicides, weeds becoming resistant to herbicide and HT rape volunteer plants.



(*Abutilon theophrasti*) demonstrated a greater tolerance to glyphosate and farmers reported problems controlling this weed with the rates of glyphosate for which they were willing to pay.[6] In Missouri, where over half the soya crop is GM, farm advisers report that waterhemp has become an increasing problem in recent years. According to them, 2001 was a "fantastic year for waterhemp," with "even good managers being frustrated."[18] In March 2002, farm advisers at the University of Mississippi reported the appearance of resistant horseweed that was requiring a six to thirteen-fold increase in the amount of glyphosate to achieve the same levels of control as normal horseweed.[15]

HT crops also encourage higher agrochemical use because they facilitate "no-till" farming. Traditionally, land is ploughed before the seeds are sown, and this mechanical action kills off many weeds. With no-till farming, however, the land is only at most surface tilled and weeds which would otherwise have been killed by the ploughing are treated instead with heavier applications of herbicide.[19]

There is also the widespread arrival of herbicide resistant oilseed rape volunteer plants in Canada, a serious problem for weed control which is leading to a much greater use of herbicides (this is reported in detail in chapter 7, 'contamination'). HT volunteers and the change in weed population, and resistance, means that in many cases farmers also appear to be reverting to older and more toxic herbicides as a result of HT crops.

Finally, the claims that HT crops would reduce agrochemical use overlooks the fact that many farmers have already begun adopting modern weed control practices which involve a greatly reduced use of herbicides. For example, integrated crop management (ICM) uses specific management practices to reduce weed problems. Organic farmers have taken this approach furthest and do not use any herbicides at all, though they do have higher costs of production as a result.

4.2 Pesticides

Two of the GM crops being grown commercially in North America produce an insecticide in their tissues: Bt maize and Bt cotton. The gene for the production of the Bt toxin was engineered into maize to reduce attacks by two caterpillar pests, the European corn borer and the Southwestern corn borer.[20] In the US, approximately 26 per cent of the total maize area was planted with Bt maize in 2001.[21]

Monsanto claimed that these crops "require less pesticide application."[22] However, overall insecticide applications on maize have slightly increased. Bt cotton has successfully produced a reduced use of insecticides overall, though problems are already being reported.

Bt maize

Despite a significant increase in the area of Bt maize, the area of maize treated with European corn borer insecticide rose slightly from 6.75 per cent in 1995 to 7.3 per cent in 2000, according to Dr Benbrook.[3] The proportion of the total maize area that was sprayed with insecticide for all pests did not decrease, but remained constant over five years at 30 per cent of the total, according to Professor John Obrycki's research team at Iowa State University.[23]

Bt cotton

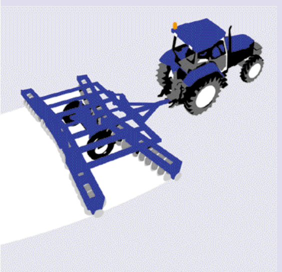
Bt cotton has successfully reduced the overall use of insecticides for bollworms and budworms. The effects, however, have varied widely from state to state, with some having almost eliminated the use of insecticides for these pests and others having almost doubled their use.[24] Reports from the US and other countries (China and Australia) indicate that total insecticide use will increase again due to the development of insect resistance and increases in other pests after a few years.[25, 26]

Why insecticide use on GM maize is up

It should have been clear from the outset that the scope for Bt maize to reduce insecticide use was limited. The European corn borer is only a problem on average one year in five, with many regions each year where it does little damage.[27] Moreover, although insecticides alone do not provide full control in an outbreak,[17] modern integrated pest control methods can achieve adequate control through specific management practices and targeted use of insecticides. Organic farming relies almost fully on alternative pest control practices and only uses very few insecticides, such as natural Bt, as a secondary means of control.

4.2 **Key points**

- ★ Bt maize has been genetically engineered to continuously produce the insecticide, Bt toxin, in its tissues
- ★ It was claimed that Bt crops require less insecticide use, but the maize area sprayed has not decreased and the amount of chemical applied has slightly increased
- ★ Bt maize can only control the European and the Southwestern corn borer, so farmers are stillapplying insecticides for other insect pests
- ★ Bt cotton has so far successfully reduced the overall use of pesticides, though the development of insect resistance is likely to lead to increased use in future
- ★ To prevent the development of insects resistance to Bt, maize farmers are advised to grow no more than 50–80 per cent of their total maize area to Bt maize
- ★ The development of resistant insects could render Bt crops redundant and undermine the less intensive use of natural Bt by organic farmers.



Bt crops can also only resist the specific pests for which they were designed, so for many farmers there is still a need to apply other pesticides. Professor Obrycki's team concluded, in a review in *Bioscience* in 2001, that the use of Bt maize would not significantly reduce insecticide use since "Bt plantings are not being used as a replacement for insecticides, but in addition to them."[23] In addition, the effects of Bt maize are limited by the fact that farmers are restricted to planting no more than 50–80 per cent of their total maize area to Bt maize by the US Environmental Protection Agency (EPA).

The general consensus for why insecticide use has increased with the introduction of Bt maize is that all the academic and industry focus on Bt maize and the European corn borer has led farmers to become more aware of their insect problems, including other pests such as armyworms. Insecticide use has gone up for all of these insects, including European corn borers.[17]

Pest resistance and 'refuges'

One problem with Bt crops is that they will encourage insect pests to become resistant to the toxin. This would not only bring the point of Bt crops to an early end, but it would undermine organic production systems.

Bacillus thuringiensis (Bt) is a naturally occurring bacteria which has long been used as a highly selective biological control agent against caterpillars in organic farming. The spores are applied in spray form when the need arises. According to a survey by the Organic Farming Research Foundation, organic growers in the US use Bt sprays more than any other product to manage insect pests; over 50 per cent use Bt frequently or occasionally.[24]

Although Bt has been used for a long time, the risk of pest resistance developing has been considerably inflated by the introduction of Bt crops. Bt toxin in GM crops is different from the use of natural Bt. Natural Bt is only applied occasionally and degrades within three days. The engineered Bt genes, however, unlike naturally occurring genes, are active the whole time and throughout the plant, so Bt crops produce the toxin continually in all their tissues. The Bt gene is also being engineered into several different crops at the same time. In response to such constant and widespread exposure, only insects with a natural immunity to the toxin are expected to survive and form the basis of a resistant population.

To address this problem, the Bt maize sector and the EPA have instigated insect resistance management plans "to preserve the benefits of this technology for years to come."[28] However, this has introduced major practical constraints on farmers who wish to grow Bt crops. The plans require farmers in the maize belt to plant at least 20 per cent of their total maize area to non-Bt maize varieties and farmers in southern states of overlapping maize and cotton production to plant at least 50 per cent to non-Bt varieties.[28] There are guidelines for how this should be done.[29]

The idea is that these Bt-free 'refuges' will maintain a population of susceptible insects for mating with Bt resistant insects, and so prevent the resistant insects from becoming dominant. Clearly, this practical restriction undermines the supposed convenience of Bt crops, and a biotechnology industry survey published in January 2001 found that nearly 30 per cent of farmers who grew Bt maize in 2000 were not following the resistance management guidelines.[30]

Moreover, research suggests that the rate of build up of resistance has been underestimated. The refuge plans were developed on the assumption that the inheritance of the Bt resistance trait would be recessive and thus slow to evolve. But research published in *Science*, in 2000 by Kansas State University shows that the inheritance of resistance may be "incompletely dominant," meaning that resistance may develop faster than originally predicted.[31]

"GMOs do not provide a quick fix solution to the economic problems of US farmers. As time goes on the technology is proving to be more of a hindrance than a help."
John Kinsman, vice-president of the National Family Farm Coalition and dairy farmer in Wisconsin[1]

5 Farmer income

"There's profit in your fields. Unleash it with Asgrow Roundup Ready soybeans… With Asgrow soybeans, profitability runs wild."
US farming magazine advert, January 2002[2]

The widespread introduction of GM crops in North America was achieved through promises of higher profits for farmers. Many farmers were in a desperate economic situation and ready to believe that GM crops could help them into a better financial state.

However, the reality has been that GM soya and maize have worsened the situation. The results differ between regions and from year to year, but overall the effect of these crops on farm incomes has been negative. Feedback from farmers and independent economic analysis of the data from six years of commercial growing show that these two GM crops deliver less income on average to farmers than non-GM crops. Furthermore, those farmers producing GM-free produce have been able to command price premiums for their produce that, by definition, GM farmers cannot access.

This section looks only at the direct impact on farmer income of GM crops (the indirect impacts of GM crops on the wider farm economy are addressed in chapter 10).

HT soya

Analysis by Iowa State University economist Michael Duffy has shown that, when all production factors are taken into account, herbicide tolerant GM soya loses more money per acre than non-GM soya. GM soya lost $8.87/acre while non-GM almost broke even, losing $0.02/acre.[3] This was based on a conservative five per cent estimate for the extra cost of the GM seed technology fee, and assumed the same market price for GM and non-GM soya, in other words the differences are likely to have been underestimated.

Bt maize

In a December 2001 report, Dr Charles Benbrook presented the results of a detailed analysis of the economics behind Bt maize. The profitability of Bt maize is variable; it is also hard to predict in advance as it depends on the level of pest problems. On an annual basis, the Bt varieties paid off on average in three of the years they were grown (1996, 1997, 2001), but not in the other three (1998, 1999, 2000). Over the whole period the outcome was negative: "From 1996–2001, American farmers paid at least $659 million in price premiums to plant Bt corn, while boosting their harvest by only 276 million bushels – worth $567 million in economic gain. The bottom line for farmers is a net loss of $92 million – about $1.31 per acre" from growing Bt maize.[4]

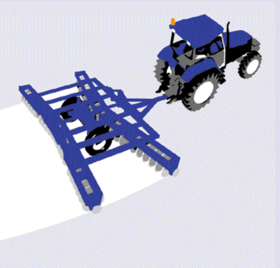
Duffy undertook a similar analysis on Bt maize. He also found little economic evidence to account for the rapid uptake of the GM variety. Returns per acre from Bt maize were slightly worse, with Bt maize losing $28.28/acre and non-Bt maize losing $25.02/acre.[3]

HT rape

There is a scarcity of independent research on the economics of growing HT rape. However, one industry study of rape growers suggested that while the herbicide use of those growing HT rape was higher, farm

5. **Key points**

- ★ Contrary to the industry claims, GM crops have reduced average farm profitability
- ★ HT soya reduced average returns by about $8.8/acre compared to non-GM soya
- ★ Bt maize reduced average returns by about $1.3-$3.2/acre compared to non-Bt maize
- ★ GM seeds are significantly more expensive than non-GM seeds as farmers have to pay a technology fee which adds 25–40 per cent to seed costs and prevents them saving seed
- ★ A significant fall in herbicide prices has offset the cost of the greater use of herbicides for HT crops
- ★ GM crops are receiving lower market prices than those available for non-GM crops; guaranteed GM-free crops are obtaining significant price premiums.



incomes were slightly higher due to higher yielding varieties, lower herbicide costs and lower fuel costs.[5] The Canadian government's Biotechnology Advisory Committee said "As of January 2001 there is no publicly available survey or data on how individual farmers have benefited from the adoption of GM crops in Canada."[6]

Why farmer incomes are down

The differences in income that a farmer will receive from growing GM crops compared to non-GM crops results from four factors, covering both higher production costs and lower market prices:

- *The technology fee for GM seed*
  Seeds are an important cost of production. For example, they typically account for about 10 per cent of total maize production costs.[7] GM seeds are significantly more expensive than non-GM seeds because the biotechnology companies charge an additional 'technology fee' on top of the seed price. Monsanto describes this as a way that growers can "share a portion" of the extra profits that the crops will deliver.[8] The scale of the fee can vary greatly depending on the crop, the company and the particular package on offer.
  With the technology fee, GM seeds cost 25–40 per cent more than non-GM seeds.[9] For Bt maize, for example, the fees are typically $8–$10/acre, about 30–35 per cent higher than non-GM varieties, though they can be up to $30/acre. RR soya can have a technology fee of about $6/acre.[4, 10]
  To buy GM seeds, farmers also have to sign a technology agreement with the biotechnology companies. This contract prohibits the farmer from saving seed (retaining a proportion of the harvest for planting the following year). With approximately 20–25 per cent of farmers traditionally saving their seed in the US, this prohibition introduces another seed cost for these farmers.
- *Yield differences*
  The biotechnology companies claimed that the higher costs would be more than offset by the higher yields and reduction in agrochemicals. However, RR soya and RR rape produced lower yields than non-GM varieties on average, and although Bt maize produced a small yield increase overall, it was not enough over the whole period to cover the higher production costs (see chapter 4).
- *Agrochemical costs*
  Agrochemicals make up a large proportion of farmers' production costs. RR soya, RR maize, Bt maize, and HT rape have mostly resulted in an increase in agrochemical use. However, because of a herbicide 'price war' that has erupted in the US, herbicide costs have fallen significantly since the introduction of GM crops. In many cases it has meant that total herbicide costs have significantly reduced. Soya herbicide prices, for example, have fallen over 40 per cent since the introduction of RR soya in 1996. This has greatly helped to offset all the higher costs of RR soya (the price of seed, the yield drag and higher agrochemical use).
- *Lower market prices*
  Farmers did not bargain for the negative effect that GM crops have had on market prices (see chapter 10). Since the introduction of GM crops a tiered market has developed. Farmers growing GM crops now receive lower market returns than previously, and also lower prices than those growing non-GM crops. The income calculations by Benbrook and Duffy did not take this into account.
  For those growing non-GM crops, market premiums are available to offset the fall in market prices. According to a survey of 1,149 grain elevators in 11 Midwestern US states by the American Corn Growers Association last autumn, almost 20 per cent are offering farmers premiums for non-GM corn and soya ranging from 5–35 cents per bushel.[11]
  The farmers who have gained in terms of market prices are those who can supply guaranteed GM-free produce, for the growing 'identity preserved' (IP) markets which have developed since the introduction of GM crops. For example, according to Minnesota farmers Susan and Mark Fitzgerald, GM-free soya receives around 50 cents/bushel more than GM, selling at $4.40/bushel (approximately a 13 per cent increase) and organic soya sells at $12/bushel, an additional premium of 200 per cent.[12]

While there are some farmers growing GM crops who have been able to cut their production costs or increase yields with GM crops, it appears that, for most producers, any savings have been more than offset by the technology fees and lower market prices, as well as the lower yields and higher agrochemical use of certain GM crops.