

who benefits from gm crops?

an industry built on myths

april 2014 | report

Friends of the Earth International



A Woman selling eggplant at a roadside stall in Mandawa, Northern Rajasthan, India.

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Friends of the Earth International is the world's largest grassroots environmental network with 74 member groups and over two million members and supporters around the world.

Our vision is of a peaceful and sustainable world based on societies living in harmony with nature. We envision a society of interdependent people living in dignity, wholeness and fulfilment in which equity and human and peoples' rights are realised.

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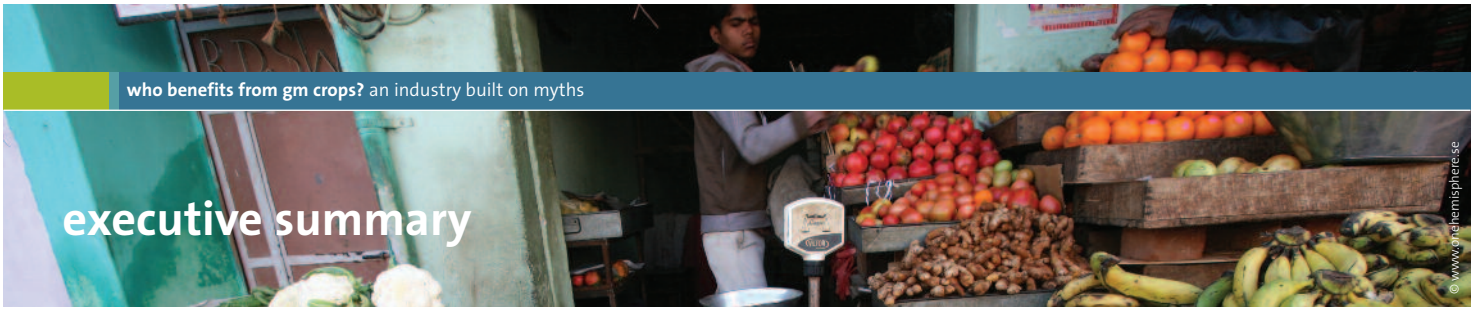
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A roadside stall in Mandawa, Northern Rajasthan, India.

executive summary: who benefits?

Our relationship with food and the way in which we farm is under increasing pressure. Extreme weather events, a changing climate and a growing population are putting the food sovereignty of communities at risk. At the same time health experts have raised serious questions about our modern diet. The World Health Organization (WHO) has warned of a 'global obesity epidemic'[1] yet an estimated 868 million people are suffering from chronic hunger.[2] It is perhaps no wonder that there are calls for a fundamental change to the ways in which we farm and feed the world.

The biotech industry has placed itself at the heart of this debate. Biotech corporations are working alongside governments and the aid community on initiatives they claim will improve yield and nutrition. Advocates argue that genetically modified (GM) crops can help to feed a climate-constrained world.

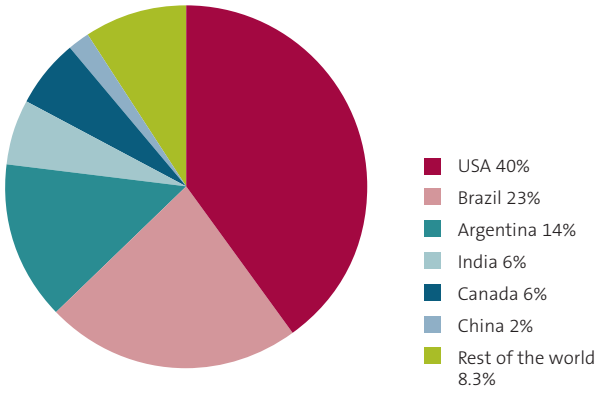
This report examines the reality of GM crop production worldwide. It differentiates the claims from the reality, drawing evidence from the experiences of small farmers and the communities who live with GM. It finds:

- *There is significant resistance to GM crops on all continents.*
- *Evidence from the cultivation of GM crops in North and South America, going back over two decades, shows increased levels of pesticide use due to weed and insect resistance – herbicide tolerant and insect tolerant (BT) GM crops do not provide an effective solution to the problem of agricultural pests.*
- *Emerging evidence of the negative impacts of pesticides on the environment and people's health suggest that these GM crops are not sustainable.*
- *There is no scientific consensus on the safety of GM crops – with many doubts and questions unanswered.*
- *Bio-fortified GM Golden Rice is not the best solution for vitamin A deficiency.*
- *Despite hype around new GM varieties for improved nutrition and climate adaptation industry figures show about 99 per cent of the GM crops grown are still herbicide tolerant, insect resistant or a combination of both.**

Where is GM grown?

There is a shortage of independent data on GM crops, with many of the figures only available from the industry bodies. These figures from 2013 show that 18 million farmers grow GM crops in 27 countries worldwide. This figure represents less than one per cent of the world farming population.[3] GM crops are predominantly found in six countries (92 per cent of GM crops) and these countries mainly grow just four GM crops: soya, maize, oilseed rape and cotton. Eighty eight per cent of arable land remains GM-free.[4]

FIGURE 1 **GM PRODUCTION OF TOP SIX COUNTRIES**



Source: *Calculations based on ISAAA (2014). Special Brief 46 – 2013 Executive Summary, Global Status of Commercialised Biotech/GM Crops: 2013, http://www.isaaa.org/resources/publications/briefs/46/executivesummary/*

* Calculations based on ISAAA Special Brief 44 (2012), http://www.isaaa.org/resources/publications/briefs/44/executivesummary/ and Nature Special Report, GMO Crops: Promise and Reality, http://www.nature.com/news/specials/gmcrops/index.html

"Our relationship with food and the way in which we farm is under increasing pressure. Extreme weather events, a changing climate and a growing population are putting the food sovereignty of communities at risk."

North America

The largest concentration of GM crops is in the United States where GM varieties of soya, maize and cotton account for 90 per cent or more of production of these crops. But there is also strong public opposition to GM in the US, with a growing campaign for GM food labelling. This has triggered fierce opposition from the food industry.[5]

The first GM drought-resistant maize was approved for commercial production in the US in 2013, but official assessments suggest it is only designed to maintain yields under moderate drought conditions, and does not perform as well as regionally adapted conventional maize.[6]

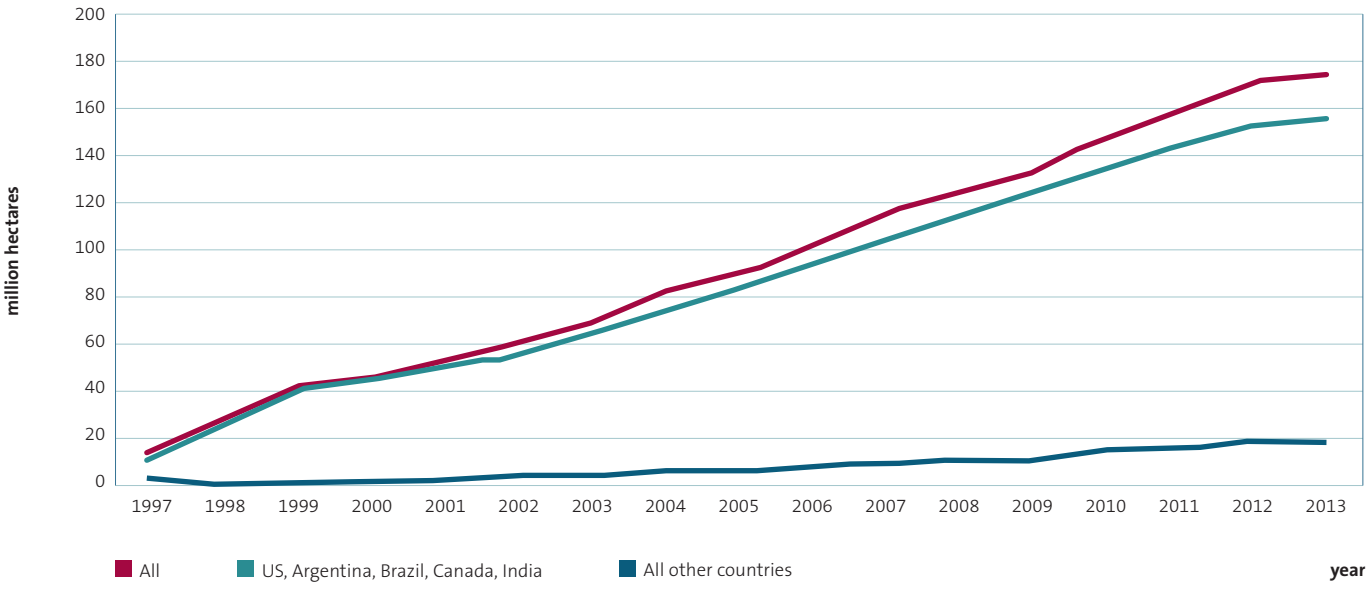
Canada has approved GM canola, maize and sugar beet, but there is no government data on how much is grown. Canada also approved production of genetically engineered fish eggs in 2013.

This is the first time that the genetic modification of an animal has been authorised for food purposes. The eggs will be shipped to Panama for production. Researchers are developing some 35 species of GM fish, using genes from coral, mice, bacteria and even humans.[7] The US Food and Drug Administration (FDA) announced it was considering an application to approve GM salmon for human consumption. Several retailers in the US and Europe have announced that they will not sell GM seafood.[8]

South America

In South America, GM soy, maize and cotton are grown most extensively in Brazil, Argentina and Paraguay. In Brazil, where 89 per cent of the soy is GM, Monsanto has been ordered to compensate farmers after a court ruled that the royalty fees being charged for Roundup Ready soy were unlawful. Claims from farmers are estimated to be in the region of $US 1 billon.[9]

FIGURE 2 **GLOBAL AREA OF GM CROPS**



Source: *Based on ISAAA annual reviews of GM crop area. *data for 1988 excludes China.*

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continued

Asia

In Asia, GM insect-resistant cotton is grown in India, China, Pakistan, and Myanmar, while GM maize is grown in the Philippines. In India, public protests led to a moratorium on the commercial introduction of Bt brinjal (aubergine). Attempts to introduce GM rice, GM papaya and GM maize to Thailand have so far failed,[10] although new varieties of GM papaya, sweet potato, cotton and abaca are under development in the Philippines.[11]

Asia has also been the testing ground for the first nutrient-enhanced GM crop, 'Golden Rice', with field trials carried out in the Philippines, with funding from the Bill and Melinda Gates Foundation. The crop has been genetically modified to increase levels of pro-vitamin A, designed to counter vitamin A deficiency which is a major problem in some developing countries and the major cause of blindness in children.[12] There is widespread public concern about the wider impacts on farmers of Golden Rice and some of the field trials were destroyed by protestors.[13] Little data is currently available about the effectiveness of Golden rice[14] in curing Vit A deficiency and there do not appear to be plans to be make it available commercially. China, one of the world's biggest rice producers, is reported to have decided not to commercialise GM rice because of concerns about safety.[15] Even advocates of Golden Rice recognise that it is not the best solution to malnutrition.

"The best way to avoid micronutrient deficiencies is by way of a varied diet, rich in vegetables, fruits and animal products.[16]

Africa

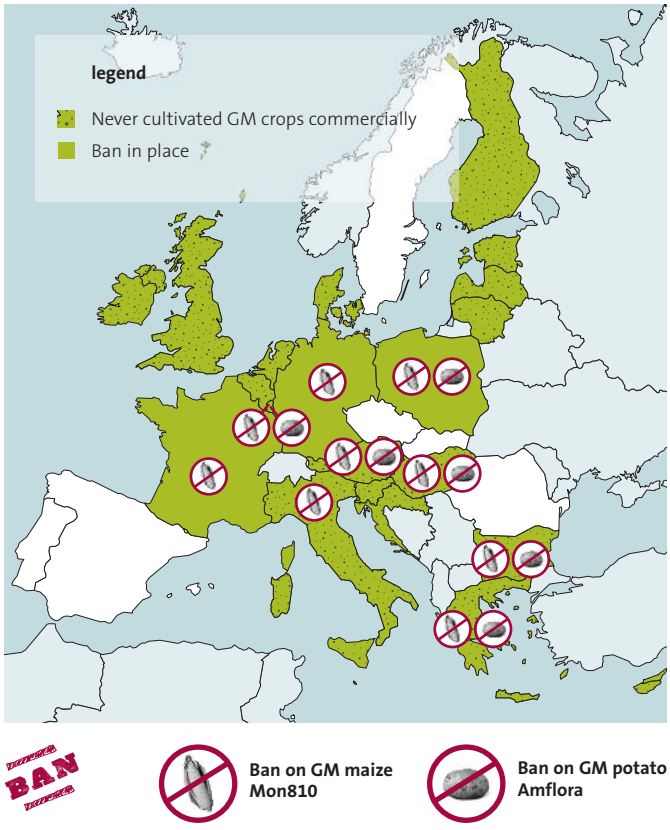
In Africa, GM crops are grown only in three countries (South Africa, Burkina Faso and Sudan), but as this report shows, the biotech industry has ambitions to extend its market into Africa, with the development of other nutrient-enhanced GM crops. Research is underway to add vitamin A and other micronutrients to African staple crops such as cassava, sweet potato and sorghum. African countries are under extreme pressure to allow GM crops in their countries, with industry associations lobbying heavily against a Kenyan decision to introduce a ban.[17]

But African countries are also increasingly looking to alternative agricultural solutions, drawing on local knowledge and research to find more sustainable solutions. Co-chair of the biggest global assessment of agricultural science and winner of the World Food Prize and Alternative Nobel Prize, Hans Herren has said that such approaches have revealed far greater success in terms of increasing yields, and in pest control.[18]

Europe

In Europe, GM crops are only being grown on around 0.14 per cent of the farm land.[19] One of the two previously authorised GM crops had its authorisation annulled by the highest European Court in 2013 and a number of European countries have banned the cultivation of GM crops.[20] In recent years public concern in the EU about GMOs has increased to 66 per cent, up four points.[21] Faced with this resistance, biotech company BASF announced in 2012 that promoting GM crops in Europe no longer made business sense,[22] and Monsanto has withdrawn some of its applications from the authorisation process. But a number of GM applications remain, including a new variety of maize recommended for approval by the European Commission in 2013 despite opposition from the European Parliament and most member states.[23]

FIGURE 3 **GMO-FREE EUROPEAN UNION**



Source: *Reuters (2013). Italy moves to ban growing of Genetically Modified Maize Type, http://www.reuters.com/article/2013/07/12/us-italy-gmoidUSBRE96B0OS20130712; EU Business (2013) Poland bans cultivation of GM maize, potatoes, http://www.eubusiness.com/news-eu/poland-biotech.llx/ ; ISAAA (2014). Special Brief 46 – 2013 Executive Summary, Global Status of Commercialised Biotech/GM Crops: 2013, http://www.isaaa.org/resources/publications/briefs/46/executivesummary/default.asp*

Evidence of impacts

While there has been no systematic international evaluation of GM crops, there is a growing body of evidence based on the experience of farmers and communities, which raises serious questions about their environmental impacts. Scientific discussions about these impacts have become highly politicised.

More than 99 per cent of the GM crops grown are herbicide tolerant, insect resistant or a combination of both.[24] These crops are essentially extensions of the pesticide-dependent model of industrial agriculture, suited to large scale, corporate-based food production. The industry claims these crops help reduce the environmental impact of these industrial models, but the evidence from farmers and rural communities suggests that this is not the case.

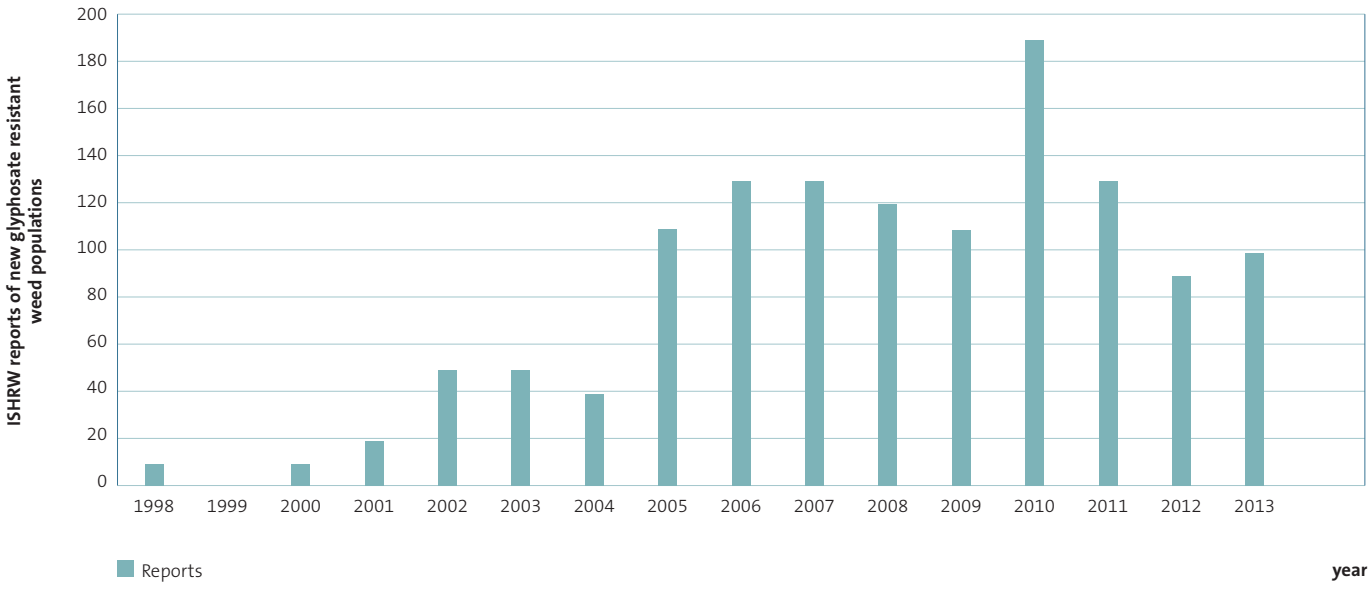
Farmers in the US, India and Argentina have reported that they need to use increasing levels of pesticides on GM crops,[25,26,27] and evidence from communities in Argentina and Paraguay has raised concerns about the health impacts of these pesticides.[28, 29, 30] Costs have also been reportedly rising for GM seeds.[31]

In the US, 21 different weed species have been identified that show resistance to glyphosate herbicides,[32] with almost half of farmers affected.[33] In Canada, 12 per cent of farmers in Ontario have reported problems with glyphosate-resistant weeds.[34] Monsanto now advises farmers to use a mix of chemical products and to plough, which would seem to undermine its claims about the supposed environmental benefits of this model of farming.

Government data from India suggests that after an initial reduction in pesticide use, farmers growing genetically modified Bt cotton need to increase pesticide use after the first two years,[35] as insects develop resistance to the toxin in the plant. A recent scientific review found that at least five species of major pests have evolved resistance to Bt crops by 2010 – up from just one in 2005.[36]

The Monarch Butterfly appears to be one victim of the spread of GM crops. In January 2014 it was reported that the number of these butterflies returning to Mexico to overwinter had declined to the lowest level since surveys began in 1993.[37] Scientists believe a major factor in the decline is the rapid disappearance of milkweed from US fields as a result of the pesticide treatment for GM resistant crops.[38,39] Milkweed is the only food source for the Monarch butterfly caterpillars – but levels have plummeted in maize and soybean fields.

FIGURE 4 **REPORTS OF GLYPHOSATE RESISTANT WEED POPULATIONS IN THE USA**



Source: *Based on data from the International Survey of Herbicide Resistant Weeds (ISHRW).*

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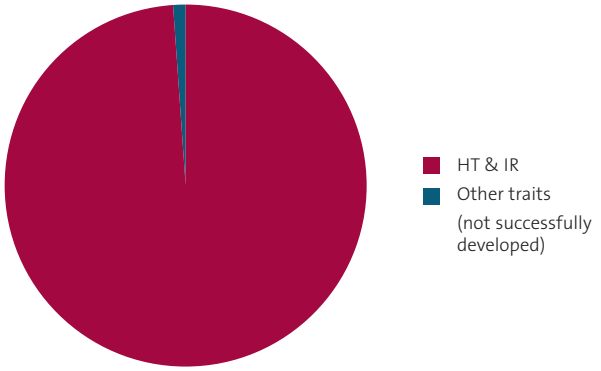
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In Argentina links have been made between high levels of pesticide use in areas growing GM crops and increased cancer rates and birth defects.[40] In the soy-growing Chaco region of Argentina, the rate of congenital birth defects is reported to have quadrupled.[41]

More than 200 scientists, physicians, academics and experts signed an open letter in 2013 declaring that there was no consensus on the safety of GM crops, highlighting the lack of epidemiological studies on the potential health effects of GM food.[42]

FIGURE 5

SHARE OF GM CROPS THAT ARE HERBICIDE TOLERANT (HT) AND INSECT RESISTANT (IR)



Source: *Based on ISAAA Special Brief 44 (2012), http://www.isaaa.org/resources/publications/briefs/44/executivesummary/ and Nature Special Report, GMO Crops: Promise and Reality, http://www.nature.com/news/specials/gmcrops/index.html*

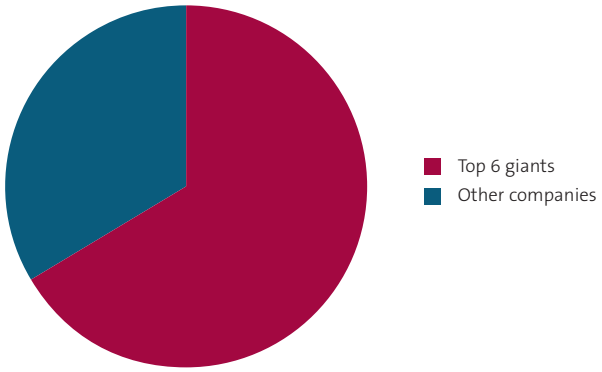
Rising costs

The rising costs of seeds and inputs reflect the near-monopoly power of the biotech companies, and the growing market concentration in the wider agricultural input sector. Monsanto controls 98 per cent of the US seed market for soy and 79 per cent of the maize market,[43] while in South Africa the company has a *de facto* monopoly over the R1.5 billion market for GM maize seed,[44] as all seeds contain Monsanto patented traits.

The high cost of seeds is seen as a particular problem for small farmers, many of whom already struggle with debt. A study in Burkina Faso found that because of the high costs, the risks of GM cotton production were *"disproportionately high."*[45] A study in the Philippines found that many GM maize farmers did not know they were growing GM maize because seeds were not clearly labelled.[46] The same study found many farmers were getting into debt because of the cost of the seeds and inputs needed.

FIGURE 6

BIOTECH COMPANIES MONOPOLIZE GLOBAL SEED MARKET



Global Seed Sales totalled US$34,495 million in 2011

The same six multinational companies — Monsanto, DuPont, Syngenta, Bayer, Dow, and BASF — control:

75% of all private sector plant breeding research
60% of the commercial seed market
100% of the GM seed market
76% of global agrochemical sales

Source: *ETC Group (2013). Gene Giants See Philanthrogopoly, http://www.etcgroup.org/content/gene-giants-seek-philanthrogopoly and ETC Group (2013) 'Putting the Cartel before the Horses and Farm, Seeds, Soil and Peasants' http://www.etcgroup.org/content/new-report-putting-cartel-horse%E2%80%A6and-farmseeds-soil-peasants#_edn1*

Tackling hunger

Those calling for a new Green Revolution argue that what is needed to tackle hunger is more intensified agriculture, which relies heavily on increasing use of non-renewable resources such as fertilizers and fossil fuels. There is mounting evidence that this system of farming is destroying the resource base we rely on to produce food.[47, 48] Genetically modified crops have been developed as part of this damaging industrial model and it seems unlikely that they can successfully be adapted to meet the challenges and needs of smallholder farmers in the poorest parts of the world.

The causes of chronic hunger are rarely to do with low crop yields *per se*, but are related to poverty, inequality of food access, and inequality of access to land and resources with which to grow food.[49] Yet much of the food we currently grow is not used efficiently. Over half of cereals produced globally go towards feeding livestock in intensive systems,[50] and approximately 1.3 billion tons of the food produced for human consumption is lost or wasted.[51]

Growing support for agro-ecology

At the same time there is growing evidence from around the world of sustainable food and farming models that guarantee food sovereignty while respecting and developing the role of small holders. The main such approach, agroecology, is both a science and a set of practices, as well as a social and political movement. It is the approach increasingly called for by international agencies as well as millions of small scale farmers. These approaches can control pests and also dramatically increase yields, doubling them in some countries.[52]

Rather than relying on expensive inputs, farmers in Africa are increasingly turning to the 'push-pull' method to control pests. For example, they use inter-cropping with repellent plants to deter the insects, alongside a border of more attractive plants which entice the pests away.[53]

Agro-ecological intensification methods have also been shown to successfully increase rice yields by as much as a third, according to studies in Kenya.[54] The ´system of rice intensification´ known as SRI, uses a less intensive method of planting for irrigated crops in order to increase yields. Organic matter is added to improve soil fertility, water use is reduced, and planting methods are designed to improve the vigour of individual plants.[55]

As a way to improve the resilience and sustainability of food systems, agroecology is now supported by an increasingly wide range of experts within the scientific community.[56, 57, 58]

BOX 1: Food sovereignty

Friends of the Earth International adheres to the definition of food sovereignty (established by the Nyeleni Forum on Food Sovereignty in 2007) as the right of all peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems.

Food sovereignty puts those who produce, distribute and consume food at the heart of food systems and policies, rather than the demands of markets and corporations. It defends the interests and inclusion of the next generation. It offers an alternative to the current trade and food regime, and directions for food, farming, pastoral and fisheries systems determined by local producers. Food sovereignty prioritises local and national economies and markets and empowers peasant and small-scale sustainable farmer-driven agriculture, artisanal fishing, pastoralist-led grazing, and food production, distribution and consumption based on environmental, social and economic sustainability. See **www.nyeleni.org**

executive summary

continued

There are cheaper, better and more readily available solutions than GM crops to address hunger and malnutrition. Governments, policy advisors, donors and international agencies should:

- *Build capacity to produce food for local consumption rather than for export, with an emphasis on small-scale farmers*
- *Increase investment in agro-ecology to support small farmers including:*
  - *Participatory research that uses small holders' traditional knowledge combined with modern approaches*
  - *Research into enabling development and access to low cost traditional varieties of seeds and livestock breeds, led by local communities*
  - *Provision of agricultural extension services so farmers can access and implement knowledge that will enable them to farm more sustainably, and which can ensure that farmers are involved in developing research programmes*
  - *Support for the establishment of farmers' cooperatives and other producer organizations for small holders ensuring local and national markets can work for smallholders*
- *End the large amounts of crops and land diverted from food to agrofuel production*
- *Introduce measures to reduce high levels of consumption of livestock products in rich countries that are eating up global grain supplies*
- *Reduce high levels of retail and household waste in rich countries, and prevent post-harvest loss in the developing world*

"There are cheaper, better and more readily available solutions than GM crops to address hunger and malnutrition."

footnotes

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Bt Corn field, Nebraska.

Genetically Modified Crops: the myth of global success

Introduction

As we head into the second decade of the century, our relationship with food and agricultural production is characterised by a number of significant challenges. In particular, farming and food security are highly vulnerable to weather-related natural disasters, such as the recent typhoon in the Philippines. Agriculture is affected by the impacts of climate change, but it is also a key driver of greenhouse gas emissions.

On another front, the World Health Organization has called for action on the 'global obesity epidemic,'[1] even while an estimated 868 million people, around one in eight of the world's population, are suffering from chronic hunger.[2] A series of global food price crises have exacerbated hunger by affecting people's access to food, and food and agricultural market deregulation has also been linked to rising obesity.[3]

Facing the prospect of world population continuing to grow until it peaks in 2050, there are increasing calls from scientists around the world for a paradigm shift in the way agricultural research is funded.[4,5]

The biotech industry and its proponents often promote genetically modified (GM) crops in the context of these challenges. Profound claims have been made: GM crops will feed the world, allow us to adapt food production to climate change and increasingly harsh environments, and enable us to tackle malnutrition. Even though many of these claims relate to future or unproven GM crops, those raising concerns about GMOs are still portrayed as being opposed to solving global problems — even to the extent that opposition to GM crops was recently called *"wicked"* by a UK government minister.* Concerns raised by people in developing and emerging nations are treated with equal disdain. In 2013, public concern about GM crops in Africa was dismissed as *"fear of the unknown"* by AGRA, an organisation that promotes GM crop production.**

This report sets out to examine the reality of GM crop production worldwide, investigate specific claims made for GM crops, and reveal the agenda of those promoting them. In particular, it shows that concerns about GM crops are legitimate and based on growing experience with industrial GM crop production, not fear or ignorance.

As a result of the impacts of agricultural production on the natural world and farmers' livelihoods, civil society groups around the world are calling for moves away from industrial monoculture farming systems towards more sustainable, ecologically diverse models of agriculture. It is time to listen to these calls. As the United Nations Conference on Trade and Development stated in 2013, it is time to wake up, before it is too late:

"World hunger is a multifaceted problem that cannot be solved by technological changes alone. Industrial agriculture is unsustainable, and technological adjustments based on genetic engineering have not been able to achieve the relevant Millennium Development Goals; instead, they have introduced products that restrict farmer-based innovation, in situ conservation and access to the locally adapted germplasm."

"Alternative agricultural models, such as agroecology, demonstrate potential to reduce poverty, increase food security and reduce agriculture's environmental footprint because they increase agro-ecosystem resilience, lower external inputs, boost farmers' incomes and are based on technologies that, for the most part can be understood, implemented and further modified by poor and subsistence farmers."[6]

Deconstructing Biotech Industry Statistics

Almost 20 years after the commercial release of the first GM crops, and despite widespread public concern about this technology, there is still no independent source for global data on GM crop adoption. Many countries do not have public registers of GM crop production, or do not publish data, or provide little by way of explanation about how figures are calculated.

The International Service for the Acquisition of Agri-Biotech Applications (ISAAA) does collect and publish figures on global GM crop production. However, Friends of the Earth International does not consider ISAAA to be a disinterested provider of information. ISAAA does not publish its accounts, and on its website its list of donors includes the biotech companies Monsanto, Bayer CropScience and Mahyco,[7] as well as Crop Life International. The latter is a global federation body representing the interests of the biotechnology and agro-chemicals industry.[8] Its company members are BASF, Bayer Cropscience, Dow Agrosciences, DuPont, FMC, Monsanto, Sumitomo and Syngenta,[9] all of whom are involved in selling GM seeds and associated products.

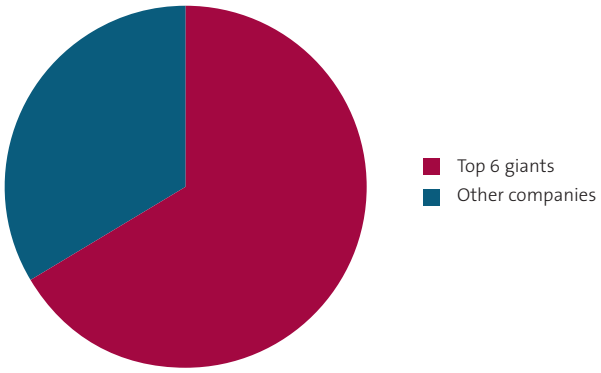
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** Alliance for the Green Revolution in Africa, 2013 'African Agriculture Status Report' http://reliefweb.int/report/world/african-agriculture-status-report-2013

Either directly or indirectly, ISAAA is supported by the six multinational companies — Monsanto, DuPont, Syngenta, Bayer, Dow, and BASF — that now control almost two thirds of the global market for seeds, three quarters of agro-chemicals sales, and the entire GM seed market (see Figure 3).

FIGURE 7

BIOTECH COMPANIES MONOPOLIZE GLOBAL SEED MARKET[10]



Global Seed Sales totalled US$34,495 million in 2011

The same six multinational companies
— Monsanto, DuPont, Syngenta, Bayer, Dow, and BASF — control:[11]

75% of all private sector plant breeding research
60% of the commercial seed market
100% of the GM seed market
76% of global agrochemical sales

Every year ISAAA celebrates an increase in the area of GM crops being grown. However, in light of some cases that Friends of the Earth International has been able to verify, there are significant questions regarding the reliability of ISAAA's data (see below).

ISAAA's position on GM crop production appears to be unfailingly positive, and it generally overlooks any problems that GM crops cause to farmers, consumers and the environment. In particular, ISAAA's annual reports present their figures as representing an inevitable and growing adoption of GM technology, but in fact the situation is less clear cut. For example:

- *ISAAA claims that 18 million farmers are currently planting GM crops in 27 countries worldwide,[12] but fails to mention that these farmers still represent **only 0.72 per cent of the world farming population**.[13] The number of countries has also fallen from 28 in 2012, because Egypt suspended GM crop production.*
- *Similarly 175.2 million ha of GM crops were planted in 2013,[14] but the global area of arable land is approximately 1.5 billion ha. This means that more than 1.324 billion ha, or **88.32 per cent of the world's arable land is still GM free**.*
- ***91.7 per cent of GM crops are grown by just six countries:** USA 70.1 million ha; Brazil 40.3 million ha; Argentina 24.4 million ha; India 11 million ha; Canada 10.8 million ha; and China 4.2 million ha.*
- *One country, **the USA, accounts for 40 per cent of global GM crop hectares**. At 70.1 million ha the USA surpasses the GM crop production of any other country. Furthermore, GM crop production in the USA and Canada together exceeds the collective production of Brazil, Argentina, India and China. In fact expansion of the GM crop area has been largely restricted to a small number of countries (see Figure 4).*
- *Eight countries were listed in ISAAA's 2013 report as growing GM crops at "less than 0.05 million" (50,000) ha, giving the impression that almost half a million hectares of GM crops could be in production in these countries. The reality is rather different. For example, Slovakia and Romania are two of the countries in this group; but only 99.9 ha of GM maize were grown in Slovakia and 834.6 ha in Romania in 2013 (see Table 1).*
- *The report glosses over the fact that **genetic modification is still largely restricted to four crops**; soya, maize, oilseed rape and cotton. GM crop varieties now account for 81 per cent of global soya production, 35 per cent of global maize production, 31 per cent of global oilseed rape production and 81 per cent of global cotton production.[16] The biotech industry has struggled to successfully market other GM crops.*

one Genetically Modified Crops

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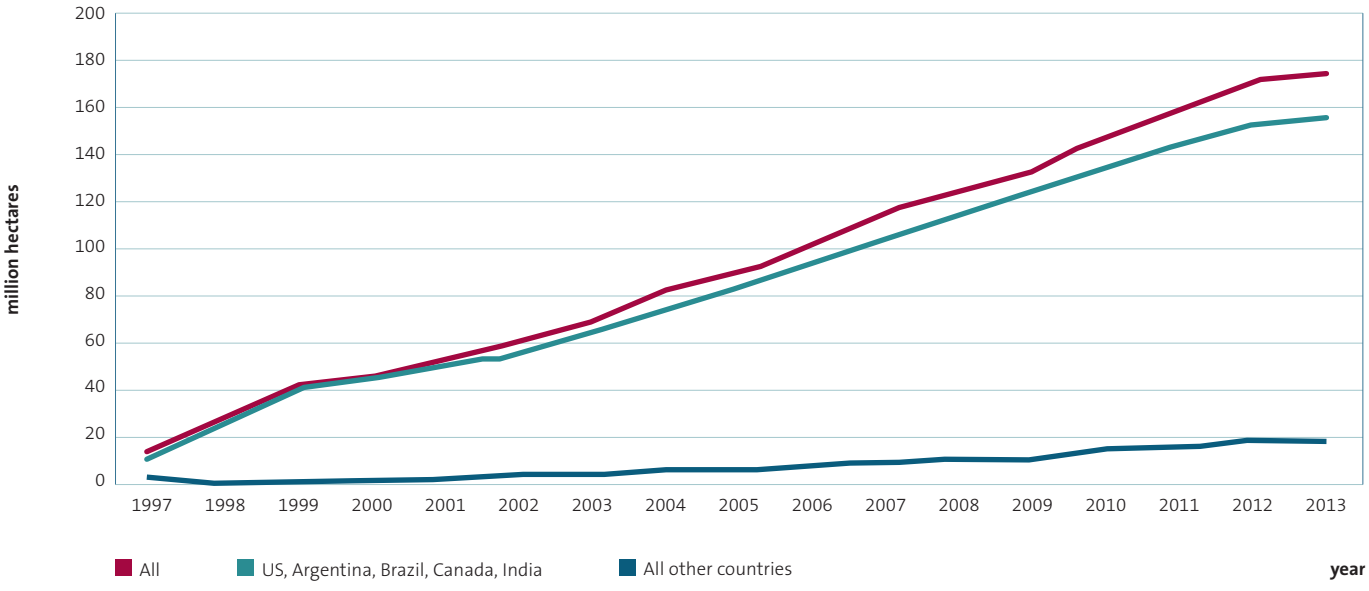
- ***GM herbicide resistance and GM insect resistance**, either alone or combined (stacked) within crops, **account for 99 per cent** of the GM traits being offered to farmers.[17] So far the biotech industry has failed to successfully develop and introduce GM crops with other characteristics.*
- ***Most GM crops are used for non-food purposes**, primarily animal feed, textiles and biofuels. For example, 70 per cent of GM maize[18] is used in animal feed. This underlines the fact that the contribution GM crops make to the food sector is limited. In particular, there has been strong opposition from consumers in several regions, and farmers have realised that they will not benefit.*

Europe

In November 2013 the European Commission (EC) gave the green light to a new GM maize (Pioneer 1507),[19] which might give the impression of a change of opinion on GMOs in Europe. But on 16 January 2014, the European Parliament requested — with a clear majority — that Pioneer's GM maize should not be authorised. On 11 February 2014 19 member state ministers (a record number) also voted against approval (compared to only five in favour).

However, under EU rules, this means the decision is referred back to the EC. An open letter to the EC, written by ministers from 12 EU governments, appealed to the EC not to allow the GM crop, stating that, *"we are convinced that the Commission cannot ignore the legal, political, and scientific concerns voiced by so many member states and the general political landscape."*[20] Nevertheless, European Commissioner Tonio Borg stated that the EC will still approve the GM crop.[21]

FIGURE 8 GLOBAL AREA OF GM CROPS[15]



In recent years public concern in the EU about GMOs has increased to 66 per cent, up four points.[22] Whether or not the EC heeds such concerns, it does appear, ironically, that the biotech industry is listening. In 2012, BASF announced that continuing to promote GM crops for cultivation in the EU *"does not make business sense,"*[23] and the company withdrew its applications for the GM Amflora potato, and two other GM potato applications. In December 2013 the European Court of Justice annulled the EC's decision concerning authorisation of this GM potato.[24]

In July 2013, Monsanto followed BASF, announcing that it would be pulling out of GM crop production in Europe, and would withdraw its applications for approval of commercial cultivation for several GM crop varieties.[25] Monsanto's true intentions with respect to the EU are still unclear however; although the company has withdrawn five applications for the cultivation of maize and one for sugar beet, applications are still within the EU approvals process for the cultivation of Monsanto's GM maize NK603 and its Round Up Ready soybean.[26,27,28,29] Nor has Monsanto withdrawn its GM MON810 maize from sale in the EU. This GM maize already has EU approval, and is cultivated in a small number of EU countries.

Furthermore, the number of EU countries growing authorised GM crops — such as Monsanto's Mon810 maize — is declining. Early in 2013 Poland joined the seven other EU member states[30] that have already banned GM crop production, by prohibiting the cultivation of Monsanto´s maize MON810 and the Amflora GM potato.[31] The Italian government also banned the cultivation of Monsanto's MON810 GM maize in 2013.[32]

Overall, official figures for 2013 showed that GM crops were being grown on a mere 0.14 per cent of the total arable land in Europe (see Table 1), and only in five EU countries. Even this figure may be inflated, because evidence from Spain — the main GM crop growing country in the EU — casts doubt on the accuracy of data supplied by the Spanish government (see below).

In the other four countries, areas of GM crop production are low and in some cases declining. Between 2012 and 2013 there was a reduction of more than 1,000 ha in the GM crop area in Portugal. There have also been ongoing yearly decreases in GM crop production area in the Czech Republic (a 16 per cent decrease since 2012) and Slovakia (a 53 per cent decrease since 2012). Although Romania showed an increase in GM maize hectares in 2013, official figures also show that only three farms in the entire country were growing GM maize.

TABLE 1 **GMO CULTIVATION IN EUROPEAN COUNTRIES, 2008–13**

COUNTRY & CROPS	2008 (ha)	2009 (ha)	2010 (ha)	2011 (ha)	2012 (ha)	2013 (ha)
Cultivation of Maize Mon810						
Spain[33]	79,269	76,057	67,726	97,346	116,306	136,962
Portugal[34]	4,856	5,202	4,869	7,723	9,278	8,171
Czech Republic[35]	8,380	6,480	4,830	5,090	3,052	2,561
Romania[36]	6,130	3,244	823	588	217	835
Slovakia[37]	1,931	875	1,248	760	216	100
Poland[38]	3,000	3,000	3,000	3,000	3,000	-
Germany[39]	3,173	0	0	0	0	0
Cultivation of Amflora potato						
Sweden[40]	0	0	103	16	0	0
Germany[41]	0	0	15	2	0	0
Total	**106,739**	**94,858**	**82,614**	**114,525**	**132,041**	**148,628**

GM crops in Spain: no transparency and inflated numbers

Based on data from EU member state governments, it appears that Spain cultivates 92 per cent of the total area given over to GM crop production in the EU, leading the ISAAA to refer to it as a *"biotech mega-country."*[42] However, the Spanish Ministry of Agriculture, Food and Environment (MAGRAMA) has been criticised by Spanish farmers, and environmental and consumer organisations for using data supplied by the industry, without verifying what is actually happening on the ground.[43] MAGRAMA calculations are based on GM seed sales data provided by seed merchants in each region, resulting in a theoretical estimation of the area that could be sown.

The ministry has confirmed that it does not verify the sales data provided by the seed industry, nor does it check whether GM seeds that have been sold in a particular region are actually being grown there;[44] in other words, GM seeds bought in one region may be cultivated in a different one, adding further confusion to the data.

one Genetically Modified Crops

continued

However, Spanish non-governmental organisations,[45] using various legal routes, have managed to collect data on GM crop cultivation themselves, from some of the regional governments in Spain, and have compared this data with the agricultural ministry's figures. Regional government data is collected through applications for agricultural subsidies, in which farmers must specify whether they are growing conventional or GM maize. The information obtained reveals large differences between national and regional government data. For example, in Andalucia there was a consistent difference of 77 per cent, between the area of GM crops estimated by the Spanish Ministry and the much smaller figures calculated using the Andalucian authority's data (see Table 2).[46]

While the data from Andalucia suggests a huge over-estimate by the Spanish government, the opposite appears to be the case in Galicia. The Spanish Ministry of Agriculture MAGRAMA has stated that there is no GM crop production in this region, but figures from the Galician authorities show that a few hectares of GM crops were cultivated in 2010 and 2012.[48]

Similarly for 2013, data for the production of GM maize MON810 shows a difference between the estimated and real figures of 73 per cent in Andalusia and 50 per cent for the total acreage across the country.[49] In other words, under 70,000 ha of MON810 were grown instead of the 136,962 ha announced by industry and the government.[50] The data certainly indicate that Spanish farmers' demand for GM seeds may in fact be far lower than is suggested by 'official' figures.

In general these discrepancies indicate that the true picture of GM crop production in Spain is quite different to that portrayed by ISAAA in its annual reports.[51] However, there is no public register of GM crop production in Spain, and without it there will continue to be little transparency about the precise area of GM crops being grown. Moreover, the lack of a public register means that in cases where GM contamination has occurred on organic farms, it is impossible to identify the source.[52]

TABLE 2 HECTARES OF GM MAIZE CULTIVATION IN ANDALUCIA ACCORDING TO DIFFERENT SOURCES[47]

SOURCE	2010 (ha)	2011 (ha)	2013 (ha)
Ministry of Agriculture (MAGRAMA)	3,773.24	5,244.09	10,361.76
Andalusian Ministry of Agriculture CAPMA	839.75	1,203.59	2,372.31
Difference	2,933.49	4,040.50	7,989.45
Percentage Difference	77.74	77.05	77.11

GM crops (and traits) pending EU authorisation

There have already been cases of GM crops being authorised but not cultivated, or being abandoned very quickly. The most recent example is BASF's Amflora GM potato. In general, approvals for the cultivation of GM crops are very limited in the EU, but there have been approvals for the import and consumption of GM crops for use in food processing and animal feed. Such approvals are very significant because they allow GM foods cultivated elsewhere in the world to be imported into the huge EU market. A memo from the EC,[53] dated November 2013, listed 49 GM products that have been authorised for import and use in food and feed including: 27 types of GM maize; 8 types of GM cotton, 7 types of GM soybean, three types of GM oilseed rape, one type of GM sugar beet, one type of GM potato and two types of GM microorganism. The companies behind these products are the big six biotech multinationals (Monsanto, Bayer, Dow, Dupont, BASF and Syngenta), and more than half of the products were developed by Monsanto. Although the authorisations are for food and feed use, the vast majority of GM products imported into the EU are actually used in animal feed, with the authorisation for food use protecting the companies in case of food contamination.

As of December 2013, the European Food Safety Authority (EFSA) had 55 GM food and feed safety assessments in process, with nine already at an advanced stage of risk assessment.[54] Forty eight of the GM organisms being considered are herbicide resistant plants, and 24 are plants modified to produce insecticidal proteins. Eight plants have other genetically modified traits, such as altered quality of oil or higher tolerance to drought (see below). Twenty four applications were for GM maize, 16 for GM soybean and 12 for GM cottonseeds. Applications for cultivation in the EU have been filed for ten of the GM plants being considered by EFSA.[55] Based on EU registries, Testbiotech[56] has calculated that Monsanto filed the highest number of applications (18), followed by Syngenta (11), Dow AgroSciences (9), DuPont/Pioneer (8) and Bayer (8).

Africa

According to industry data, in the entire African continent there were only three countries growing commercial GM crops in 2013: South Africa, Burkina Faso and Sudan.[57] The total area of GM crop cultivation in Africa represents 0.54 per cent of available arable land (630 million ha).[58] In 2012 Egypt was reported to have grown 1,000 ha of GM maize,[59] but this was put on hold in 2013, due to a government review.

Apart from South Africa, the adoption of GMOs in Africa has been slow and has often met with public opposition. However, there are several countries conducting controlled field trials of GM crops, and it is thought that some countries are close to granting commercial approval of GM crops, including Cameroon, Ghana, Kenya, Malawi, Nigeria, Uganda and Ethiopia.[61,62,63]

TABLE 3 **GM CROP PRODUCTION IN AFRICA[60]**

COUNTRY	GM CROP	TOTAL AREA IN 2013 (ha)
South Africa	Maize Soya Bean Cotton	2,900,000
Burkina Faso	Bt Cotton	474,229
Sudan	Bt Cotton	62,000
Total		**3,436,229**

External pressure mounts

Many African countries are cautious about GM crops and foods, and have introduced bans on imports. Angola, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Swaziland, Zambia, and Zimbabwe have all banned GM food unless it is milled. Kenya has totally banned GM food imports[64] and Tanzania has introduced a strict ban as well.[65] But pressure to lift the bans is being exerted on them.

For example, organisations such as the Africa Biotechnology Stakeholders Forum, the African Agricultural Technology Foundation, the International Service for the Acquisition of Agri-biotech Applications (ISAAA), the Program for Biosafety Systems, Africa Harvest Biotech Foundation International, Biotechnology Trust Africa, the Seed Trade Association of Kenya, the Cereal Millers Association and the East African Grains Council[66] have all made statements against the Kenyan ban. In Tanzania, the government has been under pressure to remove a liability clause for GM crops (in cases of harm to the public or the environment), reportedly after issues raised by multinational companies[67] and foreign donors.[68]

The debate in many countries rages as hotly as it has in the rest of the world, but African concerns about GM crops have often been portrayed as being based on ignorance, effectively dismissing them. For example, a 2010 report by the Washington-based think tank the Center for Strategic and International Studies stated that, *"the absence of a scientific community—outside of South Africa—meant there was no constituency to lead and inform the debate on genetic modification technology."*[69] Similarly, a 2013 report by the Alliance for the Green Revolution in Africa (AGRA) on the status of African agriculture dismissed growing public opposition to GM foods in Africa as *"fear of the unknown."*[70] In October 2013, the Washington Post said that GM foods *"should be part of Africa's food future"*[71] and that *"it is a shame to abandon these crops based on irrational fears and suspicions."*

In response, the Alliance for Food Sovereignty in Africa (AFSA) — a pan-African coalition of organisations representing smallholder farmers, pastoralists, hunter gatherers, indigenous tribes, citizens and environmentalists — commented that *"the promotion of GMOs as solution is too often disrespectful to African culture and intelligence and based on a shallow understanding of African agriculture."* The group went on to state that the promotion of GM crops is *"recommending that African farmers develop a long-term, perhaps irreversible, cycle of dependence on the interests of a small handful of corporate decision-makers to determine what seeds, with what genetic characteristics, and requiring what chemical inputs, will be produced and made available to Africa's people."*[72]

Hans Herren, an agricultural expert, and farmer with 27 years' experience in Africa, is one of the leaders of the UN's International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD). He added to this argument pointing out that the Washington Post article did not make any reference to alternative agricultural solutions developed within African countries by institutions such as ICIPE:[73] *"I can attest that local R&D has developed and disseminated successful sustainable technologies that have not only increased yields by 200 to 300 per cent (dwarfing the expected 25 per cent) - as proven in the case of maize using the Push-Pull, or SRI for rice technologies in Eastern Africa, or permanently controlled pest such as the cassava mealy bug with natural methods across the continent - but also continuously adapted them to new local challenges, including climate change."*[74]

one Genetically Modified Crops

continued

BOX 2: Feeding the world

It is often claimed that GM crops are needed to meet the demands of a growing population. But the causes of chronic hunger are rarely to do with low crop yields *per se*. Rather they tend to be related to poverty, inequality of access to food, and inequality of access to land and resources with which to grow food.[75]

For example, South Africa has been growing GM maize since the late 1990s. A study by the World Health Organization did find a significant reduction in food insecurity between 1999 and 2008, but pointed out that this was due to government nutrition programmes and improvements in social welfare. Furthermore it found that even by 2008, *"the nutrient density of the diet consumed by South African children is insufficient to meet their nutrient requirements. Similarly, they have shown alarmingly low food variety and household dietary diversity scores."*[76] Income and access to food were found to be the crucial factors affecting households, and the report recommended the promotion of subsistence farming.

More than 70 per cent of food insecure people live in rural areas of Africa, Asia, Latin America and the Near East.[77] A high proportion are family farmers and smallholders, often unable to afford the high-input technologies associated with intensive monoculture farming and GM crops. For such farmers, sustainable farming systems offer genuine hope. A report by the United Nations Special Rapporteur on the Right to Food, based on an extensive review of existing projects and scientific literature, concluded that, *"to date, agro-ecological projects have shown an average crop yield increase of 80 per cent in 57 developing countries, with an average increase of 116 per cent for all African projects,"*[78] and that *"recent projects conducted in 20 African countries demonstrated a doubling of crop yields over a period of 3-10 years."*[79]

South Africa

South Africa was the first country on the continent to cultivate GM crops. More than 95 per cent of maize production in South Africa is by large commercial farmers. There are no official records, but a survey based on commercial sales data estimated that in 2007/8 small holder plantings of GM maize amounted to 33,700 ha,[80] or two per cent of the national GM maize crop.[81] It is worth noting that GM maize in South Africa is a staple food, meaning that it is part of the daily diet. 60 per cent of South African white maize production is destined for human consumption, and currently 80 per cent of that white maize is GM. This means that GM maize ends up in the South African food chain and may be eaten daily in an unprocessed form, such as milled and boiled into porridge.[82] In many other countries, even the United States and Canada, GM crops largely go to non-food uses such as animal feed or biofuels, leaving the South African population as one of the few eating GM foods directly.

According to a recent report from the African Centre for Biosafety[83] which focuses on South Africa, the early adoption of GM technology meant that it arrived before the introduction of appropriate legislation and administrative procedures, which led in turn to a lack of proper monitoring and safety assessment in the country: *"the decision to approve Monsanto's product as early as 1997 allowed Monsanto to colonise the production of South Africa's staple food through aggressive acquisitions of the South African seed industry and patent laws protecting Monsanto's GM technology."*[84]

A further consequence is that farmers in South Africa are already facing maize pests (stem borers) that have developed resistance to the Bt toxin in Monsanto's GM maize MON810.[85] Monsanto has had to compensate South African farmers who have experienced damage to more than 10 per cent of their genetically modified (GM) insect resistant crops. Some farmers experienced as much as 50 per cent of their crop being affected by insect infestation.[86] MON810 GM maize has now been withdrawn in South Africa and Monsanto has replaced it with MON8903 GM maize, which expresses two different forms of the insecticidal Bt protein (known as a 'stacked' variety) in an attempt to overcome the insect resistance problem.

However, despite its failure in South Africa, Mon810 GM maize is still being pushed in other African countries such as Kenya, Tanzania, Mozambique and Uganda for field trials and eventual commercialisation.[87]

Insect resistant maize for Africa

One particular African GM maize project that has been dogged by problems (relating to intellectual property rights) is the Insect Resistant Maize for Africa project (IRMA), which is funded by the Syngenta Foundation.[88,89] The stated aim of this project was *"increasing maize production and food security through the development and deployment of insect resistant maize to reduce losses due to stem borers,"* and that it would act *"as a model of how major scientific and development projects will be carried out in future, through innovative partnerships and through institutional and disciplinary collaborations."*[90]

Despite these aims, it eventually became evident that it was going to be very difficult to find Bt genes to fight the stem borer that were not already patented by biotechnology corporations. At the beginning of the project, Bt genes for insertion into GM maize plants were sourced from Ottawa University, on the basis that they would be used for *"research purposes only."* Ottawa University was chosen as the source of the Bt genes, because as a public institution it was believed this would build trust in the project. Then, in 2006, the management of the IRMA project asked Ottawa University to license the Bt genes for use in commercial varieties, so these could be sold to farmers. At this point, it was found that the intellectual property rights relating to the Bt genes were in fact held by a number of different private companies. Ottawa University would not risk an agreement for the commercial development of the IRMA Bt maize varieties, because it feared lawsuits from the companies that 'owned' the Bt genes.[91] As a result, the GM maize varieties developed by IRMA could not be used by farmers.

BT cotton

In 2013, three African countries cultivated GM cotton: South Africa, Burkina Faso and Sudan. In 2014, the Ethiopian government announced plans to start growing GM cotton as well.

South Africa was the first country to adopt Bt cotton, beginning in 1998, but this did not halt the continuous decline in South African cotton production, which has been going on since the late 1980s. This decline is mainly due to the decrease in cotton prices relative to other crops such as maize, sugar cane and sunflowers. GM cotton in South Africa represents less than one per cent of total biotech crops planted in the country.[92]

Large farmers dominate South African cotton production, but smallholders also adopted Bt cotton. An analysis of studies examining their experiences found that although yields did rise (from a very low base), the reduction in pesticide applications was *"hardly substantial"* and, due to the technology fee, buying GM seeds represented 70-80 per cent of smallholders' costs for GM cotton (up from 40-50 per cent for non-GM seeds).[93] The authors note that *"from the perspective of financially resource-poor farmers, this increase implies greater financial risk because the expense is incurred early in the season and cannot be adjusted."*

The second country to introduce GM cotton was Burkina Faso in 2008. This was the first country in Western Africa to allow commercial GM production. Burkina Faso has been hailed as a biotech success story, with claims that large increases in national production are due to the introduction of GM cotton.[94] But according to data from the pro-GM Burkina Biotech Association,[95] while GM cotton production grew significantly between 2011 and 2012 non-GM production grew even more (see Table 4), and the percentage of GM cotton in terms of total output actually decreased. There are also claims from NGOs in the country that small farmers have reported lower yields and reduced profit with GM cotton, and that overblown predictions in the media led to high early adoption rates.[96,97]

A study of Bt cotton in Burkina Faso, published in 2013, found that high seed costs were a problem for small farmers and the risks of GM cotton production were *"disproportionately high"* for resource-poor farmers.[99] A 2010 survey of cotton farmers, conducted by Traidcraft UK, reported that while conventional and organic cotton seed cost 3000-3,500 CFA per hectare, the price for Bt cotton seed was 27,000 CFA per hectare – up to nine times more expensive.[100] They also reported local concerns that Bt cotton seed was being *"unduly promoted without sufficient regard to the concerns and needs of most farmers."*[101]

It was not possible to obtain evidence about the situation in Sudan.

TABLE 4 **COTTON PRODUCTION IN BURKINA FASO[98]**

YEAR	GM COTTON PRODUCTION (tonnes)	NON-GM COTTON PRODUCTION (tonnes)	TOTAL	% GM
2011	260,680	156,447	417,127	62.49
2012	313,781	302,016	615,796	50.96

Future products

Besides maize, cotton and soya, research projects in Africa are working towards the commercial cultivation of genetically modified cassava, bananas, and sweet potato crops that are resistant to viruses that affect these crops.[102] It has also been reported that GM cassava with enhanced vitamin A content was tested in Nigerian fields in 2013.[103]

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TABLE 5 SUMMARY OF FIELD TRIALS OF GM CROPS IN AFRICAN COUNTRIES (2010)[104, 105]

COUNTRY	CROP/TRAIT
Burkina Faso	Bt cotton (approved for commercialisation) Cowpea (insect resistance) Research into GM mosquito
Egypt	Maize (insect resistance; approved for commercialisation) Cotton (salt tolerance) Wheat (drought tolerance) Potato (viral resistance) Cucumber (viral resistance) Melon (viral resistance) Tomato (viral resistance)
Kenya	Maize (insect resistance) Cotton (insect resistance) Cassava (viral resistance) Sweet potato (viral resistance)
Ethiopia	Bt cotton (commercial trials in 2014)
Nigeria	Cassava (nutrient enhancement) Cowpea (Maruka insect resistance) Biofortified sorghum
South Africa	Maize (drought tolerance) Maize (herbicide tolerance) Maize (insect resistance) Maize (insect and herbicide tolerance) Cassava (starch enhancement) Potato (insect resistance) Sugarcane (alternative sugar) Cotton (insect and herbicide tolerance)
Uganda	Banana (fungal resistance) Maize (drought tolerance) Bt cotton (insect resistance) Cotton (herbicide tolerance) Cassava (viral resistance) Sweet potato (weevil resistance)
Ghana	In 2012 and early 2013, three Confined Field Trials (CFT) applications were reviewed and approved by the National Biosafety Committee (NBC) to commence in 2013: • Insect resistance cowpea • High protein sweet potato (nitrogen-use efficiency, water-use efficiency) • Salt tolerant (NEWEST) rice A multi-location trial of Bt cotton was also approved. Bt cowpea and Nitrogen-Use Efficiency (NUE) rice and the multi-location trial of Bt cotton were already underway.
Malawi	Bt and herbicide tolerant cotton
Cameroon	Bt cotton

BOX 3: GM drought tolerant maize

For many years there have been promises that the genetic modification of crops will lead to GM crops suitable for growing in drought-prone and salty soils, often referred to as 'climate ready' crops. Between June 2008 and June 2010, more than 1,600 patent documents were published relating to 'climate ready' GM plants,[114] with Monsanto, BASF and Dupont accounting for two thirds of these patents.[115] The stakes are high; in 2010 the global market for drought tolerant maize was predicted to be worth a potential US$2.7 billion.[116]

The first GM drought-resistant maize was approved for commercial production in the US in 2013. The US Department of Agriculture's final environmental assessment of Monsanto's GM maize noted that the GM plant was designed to maintain yields only under conditions of 'moderate' drought stress (up to 20 per cent less water than normal), and that for many other characteristics the GM maize did not differ from conventional varieties. In fact, drought resistant maize varieties have already been developed through conventional (non-GM) breeding techniques, and the GM maize did not perform any better than these: *"the reduced yield-loss phenotype... does not exceed the natural variation observed in regionally-adapted varieties of conventional corn. Thus, equally drought resistant corn varieties produced through conventional breeding techniques are readily available."*[117]

The Union of Concerned Scientists (UCS) has pointed out that natural drought tolerance involves many genes corresponding to different ways that a plant can react to drought. As only a few genes can be manipulated at a time and droughts vary widely in severity and duration the expected results may not be the desired ones.[118] Not only this, the strategies used by plants to deal with dry conditions (such as slow growth) are often unsuitable for crop plants, because they cause yield reductions in normal conditions, or affect normal crop growth.[119] To complicate things, drought not only comes in different intensities, but different cycles, and can vary from year to year, or alternate with wet conditions.

North America

According to the latest ISAAA annual report,[106] the US is the world's top producer of GM crops (70.1 million ha) and Canada is the fifth largest (10.8 million ha). Together, these countries account for half of the GM crops grown globally.

USA

The most widely adopted GM crops in the US are soya, maize and cotton. A survey of major crop-growing states by the US National Agricultural Statistics Service (NASS) found that GM soya made up 93 per cent of total soya production in 2013. GM maize was 90 per cent of the total maize crop, GM cotton was 90 per cent of the total cotton crop[107] and GM canola (oilseed rape) was 90 per cent of the total crop. 95 per cent of the sugar beet crop was GM,[108] and more than 75 per cent of the Hawaiian papaya crop was GM. No data was available for alfalfa and squash, although GM varieties are on the market.[109] Yellow squash, papaya and sweet corn may be sold and eaten as whole foods (as opposed to only being sold after processing).

After almost 20 years of GM crop production in the US, two GM traits continue to dominate: herbicide tolerance, insect-resistance and combinations of these two traits in 'stacked' varieties.[110] The exceptions are GM papaya and GM yellow squash, which are virus resistant. However the GM yellow squash has only been cultivated on a limited scale, because the GM varieties are not resistant to all the viruses that attack squash plants.[111] The problems and issues experienced in the US are dealt with further in Chapter 2.

Many GM crops, including fruits, vegetables and nuts, are being tested in field-trials in the US, and GM food products pending approval for cultivation include plums, rice, wheat, apple and salmon (see Table 6 for details).

TABLE 6 **GM CROPS IN THE US PIPELINE[112]**

PRODUCTS IN PIPELINE	TRAITS	STATUS APPROVAL
GM plum	Disease resistant	Approved but not on the market or cultivated.
GM rice	Herbicide Tolerant and Insect Resistant	Approved for food and cultivations but not on the market or cultivated.
GM wheat	HT and Fungal Resistant	Approved as food – but not for cultivation.[113]
GM apple	Contains an enzyme preventing the apple from going brown.	Currently under review.
GM Salmon		Currently under review.

The US movement for food labelling is heating up

'Just label it'[120] (JLI) is a large US movement with more than 600 participating organisations[121] that is demanding the right to know about GM ingredients in foodstuffs. Repeated polls, from 1999 up to the present, have shown that a majority of the US public is in favour of GM labelling, averaging 90 per cent in support of the suggestion.[122] In 2012, a poll revealed this support was consistent across voter groups, with 93 per cent of Democrats, 90 per cent of Independents and 89 per cent of Republican voters being in favour of labelling.[123] Despite this, successive US governments have resisted calls for GM foods and GM ingredients to be labelled. In 2011, the Center for Food Safety submitted a legal petition to the US Food and Drug Administration (FDA) calling for the mandatory labelling of GM foods.

The battle to pass state laws in Washington and California has highlighted the force of the opposition, which includes powerful corporations such as Monsanto, General Mills, Kraft, Pepsico, Coca Cola and Nestle.[124] It also demonstrates their ability to influence public opinion by providing millions of dollars for their 'No' campaign.

The behaviour of this lobby even prompted Washington State's Attorney General, Bob Ferguson, to file a suit against the Grocery Manufacturers Association (GMA) for violating the state's campaign disclosure laws. The GMA is a lobby group representing the interests of brands such as General Mills, Kellogg's, Kraft and Pepsico. Ferguson alleged that the GMA, which was the largest contributor to the 'No on 522' campaign, illegally collected and spent a sum of US$7.2 million to defeat Washington's GM labelling initiative, while hiding the identity of its contributors.[125]

In June 2013, Connecticut and Maine passed GM labelling laws, but they were laws with a catch: they would only enter into force when neighbouring states passed similar laws. However, Colorado, Hawaii, New York, Vermont, and Oregon are also considering bills, and according to the Center for Food Safety, nearly half of US states introduced bills requiring the labelling of or prohibiting GM food in 2013.[126] In October 2013, there were reports in the media that Los Angeles is considering a ban on the cultivation, sale and distribution of GMOs, which would make it the largest GMO-Free zone in the USA.[127]

In January 2014, members of Congress together with 200 organisations called on President Obama to fulfil his 2007 campaign promise to label GM foods. This call was prompted by the US Department of Agriculture (USDA)'s announcement that it had approved Dow's new herbicide resistant GM maize and soybeans, which have been modified to be tolerant to the herbicide 2,4-D. There are concerns that this approval will lead to widespread spraying of this toxic herbicide, which was a major ingredient of the defoliant Agent Orange, used in the Vietnam war.[128]

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Canada

Canada has approved varieties of GM canola (oilseed rape), maize (including sweetcorn), soya and sugar beet. The Canadian government does not produce any statistics on GM crop production area, although it is thought that 100 per cent of the Canadian oilseed crop is GM.[129]

The Canadian government publishes a list of pending GM products. However, the list is voluntary. Furthermore, there is no requirement to list GM animals, while novel products that are a product of conventional breeding are also included.[130] Recently published submissions for GM crops include: 'stacked' insect resistant soybean; alfalfa modified for reduced lignin content; cotton tolerant to two herbicides; and apple modified to be non-browning.[131]

GM Salmon

'AquAdvantage Salmon' is a GM Atlantic salmon, which is claimed to be faster growing than other farmed salmon. If approved, this would be the first GM animal allowed to enter the food supply by any regulatory agency in the world. At least 35 other species of genetically modified fish are currently under development, including trout, tilapia, striped bass, flounder and other salmon species — all modified with genes from a variety of organisms, including other fish, coral, mice, bacteria and even humans.[132]

AquaBounty Technologies applied for approval of the GM Atlantic salmon for human consumption in the US, but intends to produce GM fish eggs in Prince Edward Island in Canada and then ship them to Panama for growing and processing. In November 2013, Canada gave the green light for the production of the GE fish eggs,[133] the process having been conducted in secret and without any public consultation.[134]

In 2013, the US Food and Drug Administration (FDA) announced that it was considering the application to approve GM salmon for human consumption. The FDA's decision would set a precedent, with approval opening the floodgates for other genetically engineered fish and animals (including cows, pigs and chickens) to potentially enter the US market. Currently there are no US laws specifically governing the production and sale of GM animals. Instead, the FDA regulates them as 'new animal drugs,' even though animal drug laws were not intended to regulate living organisms, that can reproduce and move independently. In addition, the animal drug approval process is confidential and mostly closed to the public, due to confidentiality laws for drug products. This severely limits public participation in the regulatory process.

The Panamanian National Environmental Authority (Centro de Incidencia Ambiental de Panama-CIAM) has identified major problems with AquaBounty's experimental production of GM salmon and the Panamanian government's oversight of this production.[135] Furthermore in January 2014 environmental groups in Canada took legal action against the Canadian government, on the basis that it had not assessed the environmental impacts of the GM salmon in ecosystems and on wild salmon species.[136] In particular, there are concerns that if fast growing GM fish were to escape from captivity they might outcompete wild species for resources, or cross breed with wild stocks. Once escaped into the wild it would be very difficult to retrieve GM salmon.

AquaBounty claims that it will only produce sterile females, in order to mitigate the risks from escaped GM salmon. However, in the project specifications submitted to the US FDA, the company stated that 95 per cent of the eggs produced would be sterile, meaning that up to five per cent of the GM salmon in each batch could be fertile.[137] Research published in the Proceedings of the National Academy of Sciences[138] concluded that a release of just 60 fertile GM fish into a wild population of 60,000 could lead to the extinction of the wild population in less than 40 generations.

The Canadian Department of Fisheries conducted research on Coho salmon that were treated with an engineered growth hormone similar to the one produced in AquAdvantage GM Salmon. The study found the treated salmon were more aggressive when searching for food (the growth hormone made them hungrier), and in some instances resorted to cannibalism.[139]

AquaBounty's record does not inspire confidence either. In 2009, AquaBounty's egg production facility on Prince Edward Island was infected with Infectious Salmon Anaemia (ISA),[140] which it failed to report to the FDA.[141] ISA is a deadly salmon virus that decimated the Chilean and Scottish salmon farming industries. In the USA, several retailers have already announced they will not sell any GM seafood, with European supermarkets making similar statements.[142]

Latin America

After North America, Latin American countries are the largest producers of GM crops. According to ISAAA, the leader is Brazil, growing 40.3 million ha, followed by Argentina (24.4 million ha), Paraguay (3.6 million ha), Uruguay (1.5 million ha), Bolivia (1.0 million ha), and Mexico (0.1 million ha). Chile, Costa Rica, Colombia, Honduras and Cuba are all listed as cultivating 'less than' 100,000 ha. Based on these figures, supplied by the industry, countries in Latin America grow approximately 40 per cent of the world's GM crops.[143]

The GM crops being grown are soya, maize and cotton, and just two GM traits dominate: herbicide tolerance and insect resistance.

The southern cone of South America has a history of soya production. In 2003 it was even dubbed the *"United Republic of Soybeans"* in Syngenta publicity material.[146] It is a vast area between Argentina, Brazil, Paraguay, Uruguay and the south of Bolivia, which has been transformed by GM soya farming. This has become the area with the highest concentration of GM crops in the world, with a reported 46 million ha of soy monoculture (not all of which is GM). These vast areas of soybeans are sprayed with over 600 million litres of glyphosate. The spread of monoculture soya production has also been linked with deforestation and land concentration.[147, 148]

TABLE 7 GM CULTIVATION IN LATIN AMERICA[144]

COUNTRY	PRODUCT	MILLION (ha)	TRAITS
Brazil	Soy, Maize, Cotton	40.3	HT*, IR** & stacked varieties
Argentina	Soy, Maize, Cotton	24.4	HT, IR & stacked varieties
Paraguay	Soy, Maize, Cotton	3.6	HT, IR & stacked varieties
Uruguay	Soy, Maize	1.5	HT, IR & stacked varieties
Bolivia	Soy	1.0	HT
Mexico	Cotton, Soy	0.1	HT, IR & stacked varieties
Colombia	Maize, Cotton	0.1	HT & IR & stacked varieties
Chile	Soy, Maize, Canola	0.03[145]	HT & IR & stacked varieties
Honduras	Maize	0.03	Insect resistant, Herbicide resistant
Cuba	Maize	0.003	

N.B.: **Herbicide Tolerant. **Insect Resistant.*

Brazil

According to ISAAA's 2013 annual report on Brazil, the country has 23 per cent of the global GM crop area, with 40.3 million ha of GM maize, soy and cotton. Based on 2012 figures,[149] 5.17 million ha of summer maize plantings are GM — 62.5 per cent of the total crop — of which 53.2 per cent are Bt insect resistant, 7.5 per cent are herbicide tolerant, and 29.7 per cent are 'stacked' varieties, containing both insect resistance and herbicide tolerance traits. The highest adoption rates for GM maize were in the southeast (88.1 per cent), the midwest (86.6 per cent) and the south (86.4 per cent) of Brazil. Winter maize (also referred to as 'second season maize crop' or 'safrinha') occupied a smaller area at 7.9 million ha, with GM winter maize planted on 6.93 million ha (87.7 per cent).[150]

Half a million hectares of biotech cotton was planted in Brazil in 2012. Around half (52.7 per cent) was herbicide tolerant, 29 per cent was insect resistant, and 18.2 per cent was stacked containing both traits. The highest adoption rates, by region, are in the north at 100 per cent, followed by the northeast at 58.5 per cent and the north/northeast at 57.1 per cent.[151]

Brazilian farmers knock Monsanto's profits

89 per cent of the soya crop in Brazil is GM,[152] with Roundup Ready soya beans accounting for 85 per cent. Monsanto charges a two per cent royalty fee on GM soybeans and GM cotton seeds sold in Brazil. Following Monsanto's attempt to extend its Brazilian patent for RoundupReady soybeans (up to 2014), a consortium of farming syndicates from Rio Grande do Sul took legal action. The court found in favour of the farmers, with the judge ruling that because the patents for RR1 soybeans had expired in Brazil, the royalty fee was unlawful and Monsanto must compensate the farmers. In 2012, the Brazilian Supreme Court of Justice decided the Rio Grande do Sul judgement applied to the entire country.[153] Lawyers for the farmers and representative bodies estimate the value of the claims against Monsanto at 1.9 billion Brazilian real (about US$ 1 billion).[154]

In its 2013 Annual Report, Monsanto stated that it had agreed to 'defer' payments, leading to a net reduction in sales profits from its GM soybean seeds of US$118 million.[155] Monsanto also allowed growers to buy Roundup Ready soybeans in 2012-14 royalty free, but only if they signed new contracts waiving their rights to any compensation.[156] The new Monsanto contracts also allow Monsanto to make inspections and increase royalty fees, and they contradict a Brazilian law that allows farmers to save their seeds for the next harvest.[157] A judge in Mato Grosso has already blocked these contracts. However, in 2013, Monsanto launched RoundupReady2 soybeans, which will be protected by a new patent and royalty fees.

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Argentina

Argentina is the third largest grower of GM crops after the US and Brazil. Argentina's soy harvest is 100 per cent GM, while 95 per cent of its maize and 99 per cent of its cotton are GM. However, cotton hectares decreased by almost half between 2011/2012 and 2012/2013 due to falling world prices and competition with soy.[158] In all, twenty four types of GM crop are approved for commercial production in Argentina: three GM soybeans, eighteen GM maize, and three GM cotton.[159] There has been much controversy about the link between the adoption of GM crops in Argentina and the explosion in agrochemical usage in the country. Initially agro-chemical use fell when GM crops were introduced, but as pests and weeds developed resistance, agrochemical use has increased ninefold; from 9 million gallons (34 million litres) in 1990 to more than 84 million gallons (317 million litres) in 2013.[160]

A study of the main soybean growing area in Argentina found that more herbicide was applied to Roundup Ready soybeans than conventionally grown beans,[161] and the environmental impact of the sprays used on GM crops was higher than those for conventional crops. An Argentinian NGO 'The Network of Physicians Working in Crop Sprayed Towns' recently conducted an analysis of data published by CASAFE (the Argentine Chamber of Agrochemicals) pointing out that since 1990 the cultivated area in Argentina increased by 50 per cent and the crop yield by 30 per cent, but pesticide use increased by 858 per cent.[162] They also point out that in the late 1990s, when GM crops first started being grown in Argentina, the recommended application rate was 3 l/ha per year; the amount being applied in 2013 was 12 l/ha per year.

Paraguay and Uruguay

95 per cent of the Paraguayan soya bean crop is Monsanto's Roundup Ready soybean. In 2012, 45 per cent of Paraguayan cotton production was GM, as was 40 per cent of the maize crop.[163] Uruguay's soya crop is 100 per cent GM (Roundup Ready), while GM maize occupied around 145,000 hectares in 2012, of which 80 per cent were 'stacked' Bt insect resistant and herbicide tolerant varieties.[164]

Bolivia

Although, 91 per cent of soya production in Bolivia is GM (Roundup Ready), GMOs are a controversial issue in the country. According to a report from USDA, the issue divides the country in two; the highlands (La Paz) oppose GM crops while Santa Cruz farmers wish to grow them. The Bolivian government has passed a Revolutionary Law that is supposed to prohibit the use of GM crops, but it is not clear whether this will be applied to GM soy production, as the law only applies to GM crops for which Bolivia is a centre of origin and diversity.[165, 166]

Chile

Chile only propagates GM seeds for export. According to a government official responsible for the area of GM crops grown in Chile, the number of hectares stated in the ISAAA report was wrong; Chile is listed as growing 100,000 ha of GM crops, but the real area is much less, at 31,000 ha.[167] GM maize accounts for 25,000 ha, GM oilseed rape 4,000 ha and GM soy around 2,000 ha.

Honduras

This is the only country in Central America that allows the field testing and commercial production of biotech crops. In 2012, there were about 33,000 ha of commercial GM maize production in Honduras, as well as several field trials of GM maize, soy, rice and bananas. The GM corn is cultivated in seven departments but is not allowed in three, the most poor. It has been restricted as a result of community requests. In addition, GM maize is not allowed to be grown close to native maize varieties.[168]

Latin American countries holding out against GM crops

GM crops have not entered South America entirely without resistance. **Peru**[169] has introduced a ten-year ban on GM crop production, by means of a regulation drafted by the anti-biotech Ministry of Environment. **Venezuela** has not approved any GM crops.[170] **Guatemala** has had a *de facto* moratorium in place since 2006.[171] **Costa Rica** is almost GM free, as 62 out of its 81 cantons have adopted legal measures to become GM-free zones,[172] and the only GM crops currently being grown are GM cotton and soy seed crops for export.

In **Mexico**, a landmark ruling suspended the cultivation of GM maize seeds for commercial use or testing. Mexico is the centre of origin and diversity of maize, and the judge based his decision on *"risk of imminent harm to the environment."*[173] This decision was the result of legal action taken jointly by farmers, scientists and human rights groups, in order to stop the Mexican government trying to lift a moratorium on GM maize production that has been in place since 1988.[174]

Finally, **Ecuador** has a constitutional moratorium on GM crops in place, although this is threatened by President Correa, who adopted a strong position against it in 2012. There is speculation that the current National Assembly, in which President Correa's party Alianza País holds an absolute majority, might consider amending the constitution to allow GM research and cultivation.[175]

TABLE 8 GM CROPS IN THE PIPELINE IN LATIN AMERICA

COUNTRY	PRODUCT	TRAIT
Brazil[176]	Sugarcane	Insect resistant
Argentina[177]	Maize	Stacked varieties
	Sugarcanes	Drought resistant (ready for commercialisation 2017) Herbicide tolerant (2014) and Bt insect resistant
	Potato	Disease resistant and herbicide tolerant*
	Wheat, maize & soy	Drought tolerant (from sunflower gene) possibly ready for 2015/2016)
Paraguay	No info available	No info available
Uruguay[178]	Maize	Stacked herbicide tolerant/insect resistant Bt11xMIR162xGA21; MON89034xMON88017; TC1507xNK603; TC1507xNK603xMON89034
	and two soybeans	Herbicide tolerant and stacked herbicide tolerant (tolerant to more than one herbicide)
		Soybean: A2704-12 (LL); A5547-127 (LL); MON89788xMON87701 (RR2YxBt); BPS-CV127-9
Bolivia	No info available	
Mexico[179]	Wheat field trials	Drought resistant
	Maize field trials prohibited	
Colombia[180]	Reseach projects Sugarcane	Disease resistant
	Rice, cassava, potato	Insect resistant
Chile[181]	Research on pine trees, stone fruit, apples, & grapes	
Honduras[182]	Rice field trials	Herbicide tolerant LL62

Asia

Production of GM crops is much lower in Asia than in North and South America. According to the latest ISAAA report, 19.1 million ha of GM crops were grown across five countries — India, China, Pakistan, the Philippines and Myanmar — constituting 10.9 per cent of global GM crop production.

The GM crop area in Asia only represents a small percentage of the total arable land in the region, and insect resistance is the dominant trait. The largest GM crop by far is insect resistant (Bt) cotton, which is the only GM crop grown in India, Pakistan and Myanmar, and the largest crop in China.

Only the Philippines grows GM maize, which accounts for approximately 28 per cent of the national maize area.[183] GM maize with stacked traits occupies the majority of the GM area (90 per cent).[184]

There have been several attempts to introduce GM rice, GM Papaya and GM maize into Thailand, but these have failed so far.[185]

TABLE 9 GM CROPS IN ASIA[186]

COUNTRY	PRODUCT	MILLION (ha)	TRAITS
India	Cotton	11	Insect resistant
China	Cotton, papaya, poplar trees	4.2	Insect resistant, Virus resistant
Pakistan	Cotton	2.8	Insect resistant
Philippines	Maize	0.8	Insect resistant, herbicide tolerant and stacked traits
Myanmar	Cotton	0.3	Insect resistant
Total		**19.1**	

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With respect to GM Cotton, India is the front runner with 10.8 million ha, accounting for 93 per cent of the total cotton area[187] in India. But this still only makes up six per cent of India's total arable land (177.5 million ha).[188] China is the next largest Asian producer of GM cotton (3.9 million ha) which represents 75 per cent of the total cotton area.[189] However, the total arable land area in China is 143.5 million ha, so GM cotton represents only two per cent of the total production area.[190] Pakistan grows 2.8 million ha of GM Cotton, which was only approved in 2012. This is 32 per cent of the total cotton area,[191] or 12.4 per cent of the total arable area in the country (22.5 million ha). In Myanmar, the cotton crop has been almost entirely GM for some years, but accounts for only 2.8 per cent of the total arable land area(10.6 million ha).[192]

Several other products are advertised by the industry as being in the process of development in Asia (see Table 10).

Chinese concerns about GM foods

Since 1997, China has approved six GM plants for commercial production — cotton, tomato, sweet pepper, petunia, poplar, and papaya. However, apart from cotton and papaya, the others are not produced or are hardly in production, due to difficulties in bringing the products through to commercialisation.[200] GM virus resistant papaya is cultivated in Guangdong on approximately 3,500 ha, and two GM tree crops (insect resistant poplar 12 and poplar 741) are planted commercially on 450 ha. However, the US Department of Agriculture and ISAAA provide different figures: ISAAA gives a larger area for GM papaya and a smaller area for GM poplar production than USDA. China does not publish government statistics on GM seed production, so it is not possible to verify these figures. However, there are reports that the biosafety certifications for the GM tomato and the GM bell pepper have been withdrawn.[201, 202, 203]

In 2009, China approved two domestically developed GM crops, a GM phytase maize which is intended to increase the absorption of phosphorous by livestock and two insect resistant varieties of rice. Then, in September 2011, China's major financial weekly, the Economic Observer, released information from a source close to the Ministry of Agriculture announcing that China had suspended the commercialisation of GM rice. Civil society groups in China had opposed what would have been the world's first cultivation of a GM staple food crop.[204] To date, GM phytase maize has still not been cleared for cultivation.[205]

TABLE 10 GM CROPS IN THE ASIAN PIPELINE

COUNTRY	GM CROP	TRAIT
China	According to the Long and Mid-term National Development Plan for Science and Technology (2006-2020), the programme will focus on crop (rice, wheat, corn, and cotton) and animal (swine, cattle, and sheep) research.[193]	Develop varieties with new traits, such as insect, disease, and stress resistance.
	GM Cotton developed by the Cotton Research Institute, Chinese Academy of Agricultural Sciences (CAAS).[194]	High quality fibre and develops big bolls.
India	Five new cotton events are under assessment.[195]	New traits and stacked event. Other traits include drought and salinity tolerance, disease resistance, sucking insect resistance, leaf curl virus resistance and traits related to cotton fibre quality.
	Public sector institutes are focusing on banana, cabbage, cassava, cauliflower, chickpea, cotton, eggplant, rapeseed/ mustard, papaya, pigeon pea, potato, rice, tomato, watermelon and wheat. The private seed companies are focusing on cabbage, cauliflower, corn, rapeseed/mustard, okra, pigeon pea, rice and tomato.[196]	
Pakistan	In 2011, the National Biosafety Committee (NBC) of the Environment Protection Agency (EPA) in Pakistan had approved 104 cases of GM crop development for laboratories, greenhouses and field evaluations, including cotton, corn, rice, wheat, sugarcane and groundnut.[197]	
	GM cotton[198]	Stacked events of HT and IR, disease resistant (leaf curl virus)
Philippines[199]	Papaya	With delayed ripening and Papaya Ring Spot Virus (PRSV) resistance.
	Cotton	Insect resistant (Bt)
	Sweet potato	Virus resistant
	Abaca	Virus resistant

Chinese consumers are not convinced about GM foods, and the GM debate is building in the country. Concerns have been fuelled by high profile scandals, such as a 2008 feeding trial of GM 'Golden Rice' by US researchers, who fed the rice to schoolchildren in Hengnan county, allegedly without informed consent from their parents. In 2012, 25 families were each granted 80,000 yuan (US$12,800) compensation.[206] An online survey conducted by Sina.com in 2013 found that 85 per cent of 30,000 voters would not buy GM foods, and 78 per cent were concerned about the health impacts of GM.[207] From 2014, the food and drug authority of Gansu in northwest China is requiring food markets to sell GM foodstuffs separately from non-GM foods.[208] There have been calls for GM labelling to be tightened, and there have even been GM protests outside the central government agricultural ministry.[209] In 2013/14 China rejected 887,000 tonnes of US maize imports because they contained Syngenta's GM maize MIR 162, for which China has not granted food approval.[210]

India and the Bt brinjal

Cultivation of Bt Brinjal, or the GM eggplant/aubergine, has been highly controversial in India and has had wider consequences for the production of GM foods in the country. In 2009, the Indian authorities approved this GM crop, but after public protest and a consultation the environment ministry announced a moratorium on commercial introduction until the fulfilment of various conditions, including the setting up of an independent regulator for GM organisms, further studies into the health and environmental safety of Bt brinjal, and a requirement for consent from state governments for field trials of GM crops.[211] As state governments are almost universally opposed to GM crop trials, there have been no GM field trials in India since 2009.[212]

Following this moratorium, the Supreme Court appointed a Technical Expert Committee to examine the moratorium and the introduction of GM food crops. The final report was published in 2013 (with one member abstaining), and it recommended that the moratorium be continued until such time as the regulatory regime in India had been strengthened and a system of safety assessment put in place.[213] As of early 2014, the issue of the moratorium on field trials was still going through the process of legal challenge and counter challenge, even leading to the resignation of an environment minister.[214] Monsanto, Bayer and BASF all have field trial applications pending.

With respect to Bt brinjal, the Technical Expert Committee commented that, *"Nowhere are Bt-transgenics being widely consumed in large amounts for any major food crop that is directly used for human consumption"* and they *"could not find any compelling reason for India to be the first to do so."*[215] Further, the committee recommended that the introduction of GM crops for which India is the centre of diversity (such as rice and brinjal) should not be allowed.

Bt brinjal was also heavily promoted in the Philippines, and has met with similar public opposition there. A court decision ordering the halting of field trials of Bt brinjal led regulators to postpone its final approval and imminent commercialisation.[216] In October 2013, Bt Brinjal was approved in Bangladesh, just before government elections.[217] The GM plant is not on sale in the country, but the Bangladesh Agricultural Research Institute has distributed plants to 20 farmers.[218] The action has been criticised both inside and outside Bangladesh, being seen as a *de facto* commercial introduction without proper assessment, and evidence of the weak regulatory regime for GM crops in that country.[219, 220]

Australia

Australia cultivates three GM crops: cotton, canola and carnation flowers.[221] There is no public register, so the only statistics for crop production are based on industry data, which states that 90 per cent of cotton grown in Australia is GM. GM Canola (oilseed rape) varieties were first introduced in Australia in 2008,[222] and GM now accounts for 10 per cent of total production.[223] According to USDA, the uptake of GM canola is slow because non-GM varieties receive a premium, especially from the European market. In addition, there are few facilities that will accept GM oilseed rape for storage and export.

South Australia and Tasmania maintain a total ban on GM crops. South Australia recently extended the ban until at least 2019, and according to the Minister of Tourism, GM free status gives the state's food and wine producers a competitive advantage in the global market place.[224] Tasmania has also just extended its moratorium indefinitely, with its Industry Minister stating *"that the indefinite moratorium was needed to maintain the integrity of Tasmania's brand and maximise future marketing opportunities."*[225]

A court case is currently running in Western Australia between an organic farmer (Steve Marsh) and his neighbour (Michael Baxter) who cultivates GM. Mr Marsh accuses Mr Baxter of contaminating his canola crop back in 2010. As a consequence, that year Marsh lost his organic certification from the National Association for Sustainable Agriculture, Australia (NASAA) for approximately 70 per cent of his property, on which he grows oats and rye and keeps sheep. Marsh is seeking damages of AU$85,000 for lost income and a permanent injunction preventing Baxter from planting GMOs within one kilometre of his farm. The case challenges the concept of coexistence between GM and non-GM and organic crops.[226] According to the Australian Associated Press, Marsh's legal costs have been partly funded from an online crowd-funding appeal, while the biotechnology giant Monsanto backed Baxter.[227]

one Genetically Modified Crops

continued

footnotes

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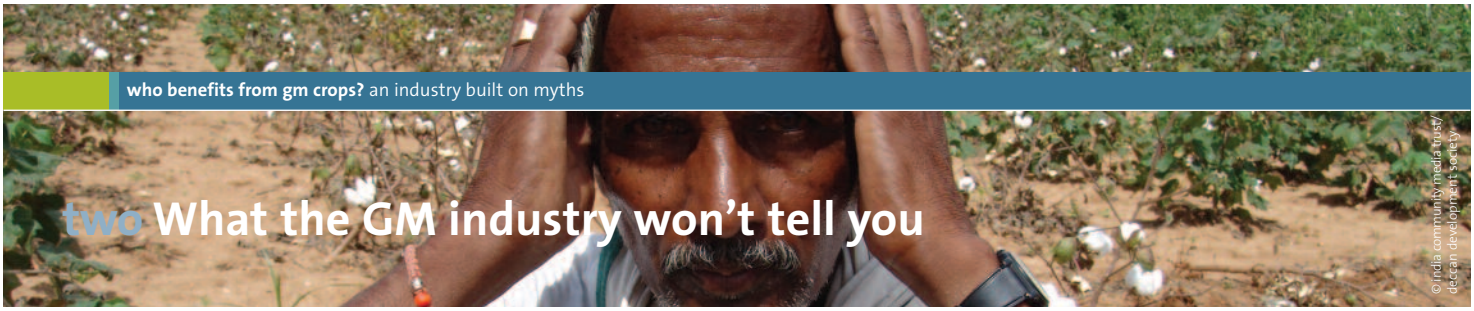
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two What the GM industry won't tell you

Cotton farmer, India.

What the GM industry won't tell you

Almost 20 years after GM crops were first planted in the United States, Canada and Argentina,[1] there is a growing body of evidence about the impacts that the industrial-scale production of GM crops is having on the environment and the livelihoods of small farmers.

While the benefits promised by the industry always seem to lie a little way into the future, current evidence — based on existing scientific evidence and the experiences of people around the world — paints a rather different picture. Without doubt, there have been winners from this technology, but the key questions are who, and at what cost?

Two GM traits still overwhelmingly dominate GM crop production. More than 99 per cent are herbicide tolerant, insect resistant or a combination of both.[2] Such crops are essentially extensions of pesticide dependent industrial agriculture, and suit this large scale, corporate based and unsustainable form of food production. But industry claims that GM crops reduce the environmental impact of industrial agriculture and help farmers:

"There is one principal and overwhelming reason that underpins the trust and confidence of risk-averse farmers in biotechnology – biotech crops deliver substantial, and sustainable, socio-economic and environmental benefits."[3]

After twenty years, what is the evidence? There have not been any systematic international evaluations of GM crops, and it is important to note that the scientific discussion about the impacts of GM crops on human health, and the sustainable development of societies, rural areas and ecosystems has become highly politicised.

Scientists whose research indicates potential risks for human health or the environment can find themselves facing well-orchestrated campaigns of criticism. The latest instance of this was the publication by Professor Seralini and his team concerning their findings about the negative health impacts of GM maize and the related herbicide on rats, which was subsequently withdrawn by Elsevier, the journal that published it.[4] Many scientists subsequently objected to this development, fearing pressure from the industry had influenced Elsevier's decision, undermining the neutrality of peer-reviewed science.[5,6,7]

As a consequence of such pressures, it is difficult to find any independent, peer-reviewed research for several areas of concern about GM crops — although some questions, such as economic comparisons between GM, conventional and organic maize production, do appear to be investigated, with the aim of underlining the benefits of the GM crop. However, after ten years of publicly-funded research in the European Union, not a single official study has been launched evaluating the costs and additional burdens that GM crop production presents for the conventional and organic food sector.[8,9,10]

This chapter will therefore include examples from around the world to try and uncover what is actually happening, especially where peer-reviewed literature is not available. This alternative evidence presents the experiences of people living with the reality of industrial GM crop production, and their voices deserve to be heard.

Herbicide use goes up, not down

When Monsanto's glyphosate tolerant 'Roundup Ready' crops were first introduced in the United States, Monsanto made claims that farmers would be able to *"use less herbicides."*[11] They emphasised the environmental benefits of using glyphosate compared to other herbicides available at the time, and said farmers would be able to grow crops without ploughing, so protecting soils. But in the United States, some experts have now begun calling glyphosate *"agricultural heroin,"*[12] because farmers became hooked on GM herbicide tolerant crops, using glyphosate continually in the same fields, year after year.[13] Even very early on in the use of GM crops, there were warnings about the rapid development of weeds resistant to the herbicide, but at the time Monsanto's own adverts claimed this wouldn't happen: *"we know that dead weeds will not become resistant."*[14] In fact, in less than two decades glyphosate resistant plant species have become a serious problem for US farmers and others around the world.

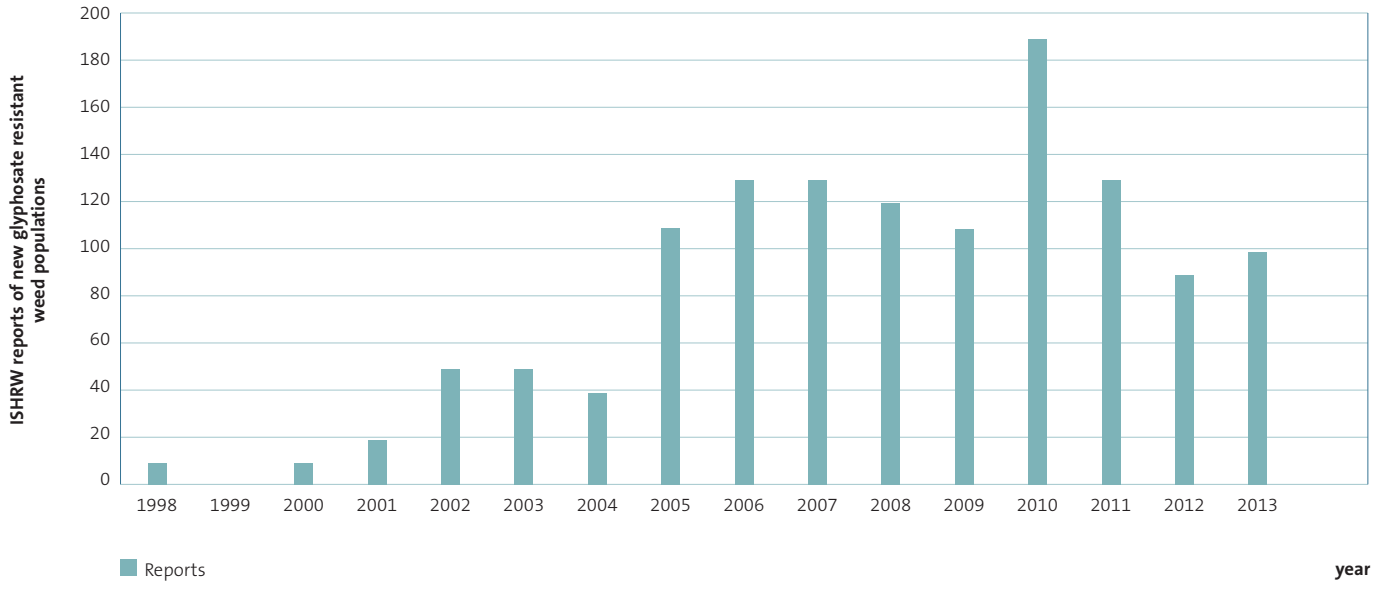
An agricultural research team from Pennsylvania State University, the University of New Hampshire and Montana State University recently rang alarm bells about the dramatic rise in herbicide tolerant weeds in the United States. *"Although herbicide resistance has most commonly occurred in the [southern states] in cotton and soybeans, it is increasing in other regions as well."* According to the research team, *"despite company-sponsored research that indicated resistance would not occur, 21 different weed species have evolved resistance to several glyphosate herbicides, 75 percent of which have been documented since 2005."*[15]

It seems that weed species are evolving rapidly in the face of GM herbicide tolerant crops. According to data from the International Survey of Herbicide Resistant Weeds (ISHRW),[16] 85 per cent of new reports of resistant weed populations in the United States have come in since 2005. In 2010, glyphosate tolerant weeds were estimated to affect 32.6 million acres in the US; by 2012 the area had almost doubled to 60.2 million acres.[17] Nearly half of all US farmers surveyed by Stratus Ag-Research in 2012 reported that glyphosate resistant weeds were present on their farm, up from 34 per cent of farmers in 2011.[18] The survey also indicated that the rate at which glyphosate resistant weeds are spreading is gaining momentum, increasing by 25 per cent in 2011 and by 51 per cent in 2012. The number of resistant species on farms is also increasing. In 2010 just 12 per cent of surveyed farmers reported two glyphosate resistant plant species in their fields; by 2012 this had jumped to 27 per cent.

This is not just a problem for the US. Other countries with large acreages of Roundup Ready GM crops are also showing the evolution of glyphosate resistant weeds. According to the ISHRW, glyphosate resistant weeds have now been found in 18 countries worldwide.

For example, Canada is following US trends. An extensive survey of 2,028 farmers across Canada revealed that 1.1 million acres of crop land had glyphosate resistant weed populations, representing 10 per cent of the GM crop area. Saskatchewan had the most acres of glyphosate resistant weeds (620,000), while Ontario had the highest percentage of affected farms (12.5 per cent).[20]

FIGURE 9 **REPORTS OF GLYPHOSATE RESISTANT WEED POPULATIONS IN THE USA**[19]



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continued

It is also reported that stronger glyphosate formulations are now being sold in Argentina, as the herbicide becomes less effective,[21] and farmers are increasingly applying mixtures of pesticides on GM crops.[22] A study by Wageningen University found that more herbicide was applied to Roundup Ready soybeans in Argentina than conventionally grown beans,[23] and the environmental impact of the sprays used on the GM crops was higher than those for conventional crops. Data produced by CASAFE (the Argentine Chamber of Agrochemicals), covering Argentina's massive period of GM crop expansion, is highly revealing. Between 2004 and 2010 the cultivated area in Argentina increased by 11 per cent, but the total applied pesticides increased by 22 per cent.[24]

In India, the Coalition for a GM-Free India examined government data on pesticide use and concluded that, *"while Bt cotton came in with the promise of drastically reducing the use of pesticides in cotton, the experience of these 10 years shows that there is no sustained reduction in pesticide usage. The experience of farmers clearly shows that while a lower number of pesticide sprays was required in the first two years of Bt cotton adoption, thereafter the pesticide requirement has increased, and now the number of pesticide sprays required is equal to or more than that in the pre-Bt cotton period."*[25]

TABLE 11 **GLYPHOSATE RESISTANT SPECIES**[26]

COUNTRY	GLYPHOSATE RESISTANT SPECIES	TOTAL
US	Amaranthuspalmeri, Amaranthusspinosus, Amaranthustuberculatus, Ambrosia artemisiifolia, Ambrosia trifida, Conyzabonariensis, Conyza Canadensis, Echinochloacolona, Eleusineindica, Kochiascoparia, Loliumperenne ssp. Multiflorum, Loliumrigidum, Poaannua, Sorghum halepense,	14
Canada	Ambrosia artemisiifolia, Ambrosia trifida, Conyza Canadensis, Kochiascoparia	4
Brazil	Conyzabonariensis, Conyza Canadensis, Conyzasumatrensis, Digitariusinsularis, Loliumperenne ssp. multiflorum	5
Argentina	Cynodonhirsutus, Echinochloacolona,Eleusineindica, Loliumperenne, Loliumperenne ssp. Multiflorum, Sorghum halepense	6

Monsanto has now changed its stance on glyphosate use, recommending that farmers use a mix of chemical products and also ploughing. In doing so, the company has completely overturned its earlier claims for the environmental benefits of herbicide tolerant crops, but the company stops short of acknowledging its role in creating the problem: *"Over-confidence in the system combined with economic drivers led to reduced diversity in herbicide use,"* is what Rick Cole, Monsanto's technical lead for weed management, has told Nature.[27] In other words, blame the farmers.

Perhaps the reason that biotech companies refuse to accept herbicide tolerance as a problem integral to the whole concept of herbicide resistant GM crops is because they are also pesticide manufacturers. Their response has thus been to start creating GM crops resistant to other herbicides — often older, more toxic ones, such as dicamba and 2,4-D.[28] The team of scientists from US universities stressed that *"the continual insertion of more genes into crops is not a sustainable solution to herbicide resistance."*[29] This will simply create a GM treadmill, no different to the pesticide treadmill of the twentieth century. The biotech companies appear to be set on locking farmers into a losing battle against evolution. As the agricultural scientists point out *"weeds will eventually evolve combined resistance to dicamba, 2,4-D and glyphosate herbicides. Globally, there are already many examples of weeds simultaneously resistant to two or more herbicides."*[30]

BOX 4: Catastrophe for Monarch Butterflies

The Monarch Butterfly (*Danaus plexippus*) is a unique species with a complex pattern of migration between Mexico, the US and Canada, taking several generations to complete it. Monarch caterpillars only feed on the milkweed plant (*Asclepias syriaca*). In 1999, a survey in Iowa found that milkweed plants were present in 50 per cent of maize and soybean fields. In 2009, following the massive adoption of GM herbicide tolerant crops in the US, milkweed was present in only 8 per cent of fields, and the area of milkweed had declined by 90 per cent.[31] In January 2014, it was reported by WWF-Telcel Alliance and Mexico's Commission for Protected Areas that numbers of butterflies returning to Mexico from the USA and Canada had fallen to the lowest level since surveys began in 1993.[32] In 1996, overwintering butterflies covered 18.6 ha of forest, but by 2013 this had crashed to just 0.67 ha. Although factors including climate change and deforestation have also been blamed for the crash in populations, scientists who have studied the phenomenon[33,34] have made it clear that the loss of the milkweed plants due to the expansion of the GM herbicide resistant crops in the USA is a major factor.

The biotech companies only seem to be able to offer farmers one approach to weed control — one that seems set to increase rather than reduce pesticide use and its impacts. This is the view of David Mortensen, Professor of Weed Ecology at Penn State University: *"I'm deeply concerned when I see figures that herbicide use could double in the next decade... What is [more] troubling is that 2,4-D and dicamba are older and less environmentally friendly [than glyphosate]."*[35]

GM crops, pesticides and people's health

One of the most controversial aspects of GM crop production and consumption is the potential impacts on animal and human health. This controversy is well reflected in a 2013 statement from the European Network of Scientists for Social and Environmental Responsibility (ENSSER), which has been signed by more than 200 scientists, physicians, academics and experts on GM-related issues.[36] This statement is a response to reports of agreement among scientists about the safety of GMOS. The ENSSER group clearly states that, *"the claimed consensus on GMO safety does not exist."* And they go on to say that, *"The claim that it does exist is misleading and misrepresents the currently available scientific evidence and the broad diversity of opinion among scientists on this issue. Moreover, the claim encourages a climate of complacency that could lead to a lack of regulatory and scientific rigour and appropriate caution, potentially endangering the health of humans, animals, and the environment."*

They add, *"Science and society do not proceed on the basis of a constructed consensus, as current knowledge is always open to well-founded challenge and disagreement. We endorse the need for further independent scientific inquiry and informed public discussion on GM product safety and urge GM proponents to do the same."*

The statement highlights areas where there are gaps in data or differing scientific opinion, including:

- *A lack of scientific consensus on the safety of GM foods.*
- *A lack of any epidemiological studies on the potential health effects of eating GMOs.*
- *Claims that government bodies endorse GMO safety which are exaggerated or inaccurate.*
- *The widely cited European Union research project entitled A Decade of EU-Funded GMO Research, which "was not designed to test the safety of any single GM" but only examined the development of testing methodologies.*
- *Internet claims that there are several hundred studies showing the safety of GMOs, which are incorrect. In fact, "some of the studies give serious cause for concern and should be followed up by more detailed investigations over an extended period of time."*
- *The fact that there is no consensus among scientists about the environmental risks of GM crops, and such opinions have even been shown, in a peer-reviewed study, to be linked to whether a scientist is industry-funded or publicly-funded.*[37]
- *Widespread recognition of the risks posed by GM foods and crops in international agreements, such as the Cartagena Protocol on Biosafety, and UN Codex Alimentarius regulations.*

In particular, there is growing concern in Latin America that GM cropping and its high use of pesticides is having serious impacts on health, especially for people living in rural areas. It is reported that safety precautions for pesticide spraying in Argentina are rarely heeded, including with respect to safety equipment for workers and exclusions intended to prevent spraying near to homes and schools.[38] Reports[39] reveal links between high pesticide use in GM crop growing areas and human health impacts, such as increases in cancer rates and birth defects:

"Dr. Maria del Carmen Seveso, who has spent 33 years running intensive care wards and ethics committees in Chaco province, became alarmed at regional birth reports showing a quadrupling of congenital defects, from 19.1 per 10,000 to 85.3 per 10,000 in the decade after genetically modified crops and their agrochemicals were approved in Argentina. Determined to find out why, she and her colleagues surveyed 2,051 people in six towns in Chaco, and found significantly more diseases and defects in villages surrounded by industrial agriculture than in those surrounded by cattle ranches. In AviaTerai, 31 percent said a family member had cancer in the past 10 years, compared with 3 percent in the ranching village of Charadai."[40]

A survey of 65,000 people in the Santa Fe region of Argentina also found cancer rates two to four times the national average, as well as higher than average rates of respiratory disease and thyroid disorders.[41] There have also been reports of increased cancer rates in Paraguay. A recent clinical study found that lymphomas and leukaemia rates had tripled between 2007-2012,[42] and that the majority of patients came from GM cultivation areas, where there is high spraying with agrochemicals.

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Sooner or later, insect resistance develops

"Insect resistance to Bt proteins is natural and expected." Monsanto[43]

The environmental and farmer benefit claimed for Bt crops is that they help reduce pesticide use, because the crops themselves produce insecticidal toxins through the expression of genes from *Bacillus thuringiensis* bacteria. However, in terms of the crop system, this is only a modification of applying insecticide sprays, and as has been found time and again with insecticides, pests can evolve resistance to the Bt toxins expressed within the GM crops. When this happens, farmers rapidly return to using insecticides.

A recent analysis by scientists from the University of Arizona, which examined 77 studies of 13 pest species from around the world, confirmed five cases of field-evolved resistance to Bt crops in major pests as of 2010. There was only one such case in 2005. Three of the five cases are in the United States.[44] According to Bruce Tabashnik, Professor of Entomology at the University of Arizona, *"You're always expecting the pest to adapt. It's almost a given that preventing the evolution of resistance is not possible."*[45] Examples from around the world bear this out:

- *In Puerto Rico, field resistance of the fall armyworm caterpillar (Spodoptera frugiperda) to Bt maize evolved within two to three years.[46] Despite the maize being withdrawn from the market, the resistance persisted, even after four years.*
- *In March 2012, 22 entomologists in the USA addressed a letter to the US Environmental Protection Agency raising their concerns with regards to the "greater than expected" western rootworm damage to Bt corn.[47]*
- *In summer 2013, it was reported by Illinois state entomologists that western corn rootworm (Diabrotica virgifera virgifera) was showing resistance to Bt maize crops expressing the Cry3Bb1 Bt toxin.[48]*
- *In a 2013 report for Third World Network,[49] a South African entomologist reviewed insect resistance development to Bt crops in South Africa. In 2007, there was the first official report of stem borer insects (Busseola fusca) showing some resistance to Bt maize.[50] The following year, stem borers fully resistant to the Bt maize had been reported, and by 2011 a survey found resistant populations all across the maize growing region of South Africa.[51]*
- *In 2010, Monsanto admitted that the Indian pink bollworm (Helicoverpa armigera) had developed resistance to its Bt cotton.[52] Monsanto introduced its next type of Bt Cotton in order to fight the resistance, but a study conducted in experimental plots at the University of Agricultural Sciences in Raichur found that the bollworm could survive on commercial Bt-cotton hybrids producing single (Cry1Ac) and double (Cry1Ac and Cry2Ab) toxins.[53]*

As a result of this growing problem of resistance, farmers in the US are beginning to use soil insecticides on Bt crops because of concerns about resistance, and as a 'cheap insurance' against the pests the Bt crops are meant to resist. An informal poll at farmer events in Illinois found that almost half of maize farmers (47 per cent) were planning to use soil insecticides on Bt crops.[54] And as noted by the same entomologist from the University of Illinois[55] when talking about the western corn rootworm, farmers in the US are *"applying enormous selection pressure to this insect species. The pressure comes in multiple forms - increasing use of Bt hybrids, neonicotinoid insecticidal seed treatments, and broadcast treatments to corn and soybean fields of pyrethroid insecticides that are frequently tank-mixed with fungicides."* This comment also shows the reality of Bt crop production in industrial farming systems, which is far from being insecticide free.

BOX 5: Push-Pull: An effective, ecological alternative to herbicide tolerant and insect resistant maize[56]

A conservation agricultural approach known as 'Push-Pull' technology has been developed for the integrated management of maize stem borers, striga weed and soil fertility. Push-pull was developed by scientists at the International Centre of Insect Physiology and Ecology (ICIPE), in Kenya, and Rothamsted Research, in the United Kingdom, in collaboration with other national partners. The technology is based on locally available plants, not expensive external inputs, and fits well with traditional mixed cropping systems in Africa, making it appropriate and economical for resource-poor smallholder farmers. By 2013 it had been adopted by over 75,297 smallholder farmers in East Africa where maize yields have increased from about 1 t/ha to 3.5 t/ha, achieved with minimal inputs.

The technology involves intercropping maize with a plant that is repellent to stem borer pests, such as desmodium, and planting a pest-attracting trap plant, such as Napier grass, as a border crop around this intercrop. Desmodium has the double benefit of suppressing Striga, a highly invasive weed of the region. The project aims to extend the technique to one million sub-Saharan farmers by 2020.

Increasing pest problems and insecticide use is not confined to the target insects of Bt crops, but also secondary pests. In China, a ten-year study[57] found that mirid bugs (insects of the Miridae family) had increased 12-fold since the introduction of Bt cotton, causing up to 50 per cent reduction in cotton yields, as well as infesting other crops. According to the researchers *"Their rise in abundance is associated with the scale of Bt cotton cultivation."*[58]

In India, there have been similar increases in a previously insignificant pest, the mealy bug.[59] Recent research has suggested that Bt crops may have lower levels of other plant defence chemicals, such as terpenoids, due to reduced attack by their target pest, and that this might make them more attractive to pests unaffected by the Bt toxins.[60]

Whether from growing resistance or secondary pests, there are now reports that in India, China and the US farmers are using more insecticides on Bt crops. In India it has been reported that pesticide use returned to pre-Bt cotton levels within three years.[61] In China, researchers predict that farmers will soon be spraying as much insecticide as they did before the introduction of Bt cotton.[62]

Prices of GM seeds and farmers' choice

"Another indication the seed market has become monopolized is the escalating prices for GE seed. [Diana Moss, Vice President of the American Antitrust Institute] points out that in competitive markets, technologies that enjoy widespread and rapid adoption — such as GE crops — typically experience steep declines in prices. The opposite has occurred with GE crops."[63]

There is a growing market concentration in the agricultural inputs sector, leaving farmers with fewer choices. A study by the US Department of Agriculture (USDA) found that in most of the agricultural input industries, market concentration increased from 1994 to 2009, with the greatest concentration observed in the animal breeding and crop seed sectors. In the USA, a review of a number of studies showed that market concentration can lead to an increase in seed prices.[64] Just four companies now account for 54 per cent of the global seed market,[65] and six companies (Syngenta, Bayer, BASF, Dow, Monsanto and DuPont) sell 76.1 per cent of agrochemicals.[66]

One company, Monsanto, dominates the US GM seed market. In 2010, it was estimated, by Dupont, that Monsanto had a 98 per cent share of the United States' soybean seed market,[67] a 79 per cent share of the US maize seed market, and 60 per cent control of all licensed soy and maize germplasm. In Brazil, Monsanto owns 89 per cent of herbicide tolerant soybeans.[68] In 2010 Dupont began action in the US courts, accusing Monsanto of anti-competitive behaviour. But this legal action was dropped in 2013 when the two companies reached a deal to share GM technologies under licensing agreements.[69]

In South Africa, Monsanto, DuPont's Pioneer Hi-Bred and Pannar Seed control the local commercial market for GM seeds. In the case of GM maize, for example, they collectively own 84 per cent of all registered varieties. In addition, all GM seeds sold in South Africa contain Monsanto's patented traits, so it would appear that the company holds a *de facto* monopoly over this market, which is worth more than R1.5 billion.[70] In 2013, after a three-year legal battle, DuPont bought a majority share in Pannar Seed, which was South Africa's largest seed company.[71]

In early 2013 it was reported that the Indian seed company Mahyco was close to buying a 49 per cent share of Quton – a company which supplies seed across southern Africa, and has secured deals into Tanzania, which is a major producer of cotton.[72] In India, Mahyco is a leading supplier of GM seeds. The Indian seed market is one of the biggest in the world and Bt cotton now represents 40 per cent of the market's total value.[73] Bt cotton accounts for 96 per cent of the total cotton production and most of the Bt Cotton contains genetic material patented by Monsanto, which has a 50:50 partnership with Mahyco.[74]

So what is the impact of the market concentration that seems to go hand in hand with GM seeds? A recent study compared the availability of seeds in European countries that had adopted GM technology (Spain) and European countries that had not (Austria, Germany, and Switzerland). It concluded that, despite excluding GM seeds, there was no evidence that farmers in non-GM countries had less choice. On the contrary, in Spain, the only country in Europe that cultivates GMOs on a large scale, the maize market was more concentrated and there were fewer maize cultivars available to farmers.[75]

In India, the GM-Free coalition argues that the seed monopoly has led to increased prices. For example, in 2004 Bt cotton seeds cost Rs 1,650-1,800 for 450 gms, as against Rs 350 for hybrid seeds and less than Rs 100 for desi cotton seeds.[76] According to the director of one Indian seed company *"much of this price of cotton seed goes towards paying royalty to Monsanto."*[77] In 2006 the Indian government imposed a price ceiling on the Bt seeds[78] for fear of monopolistic tactics. Bt cotton seed prices have fallen in the last year due to over-supply as farmers have switched to other, more profitable crops.[79]

In the US, GM seeds are much more expensive than the conventional ones. According to one analysis of USDA data, the cost of a bushel of non-GM soybean seed was US$ 33.70 in 2010, compared to US$ 49.60 for a bushel of GM soybean seed,[80] making it 47 per cent more expensive. In the case of maize, non-GM seed prices were US$ 58.13 per acre planted in 2010, but the average cost of GM maize seed per acre was US$ 108.50, with some GM cultivars selling for over US$ 120 per planted acre.

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The impact of GM crops on seed prices is illustrated by the fact that from 1975 to 2000, the 'all soya bean' seed price rose about 63 per cent in the US, but in the next 12 years, following the introduction of GM soybeans, the price of seed rose by 211 per cent.[81] This price rise was not reflected in a corresponding increase in the value of crops. Between 1994 and 2010, the rate of increase in seed prices was more than double the rate of increase in prices that farmers received for their agricultural produce.[82]

Whether US farmers are able to buy cheaper non-GM seeds is another matter. It is reported that non-GM seeds are sold by GM-dominated dealerships well above their real cost, to dissuade farmers from switching. *"We don't want our farmers to buy it,"* one Pioneer dealer is reported to have admitted.[83] Despite this, an independent non-GM seed company has reported annual growth in sales of 30 per cent.[84]

In 2013, the US NGO Centre for Food Safety produced a report called 'Seed Giants vs Farmers,' which analysed how patent protection for GM seeds — in combination with technology agreements — had drastically reduced US farmers' rights to save seed from their harvest to replant the following year. The report details the way the biotech companies use lawsuits against farmers for alleged infringements of patent rights.[85] Monsanto has a very clear view on the age-old farmer practice of saving seed: *"the practice of some farmers of saving seed from non-hybrid crops (such as soybeans, canola and cotton) containing our biotechnology traits has prevented and may continue to prevent us from realizing the full value of our intellectual property."*[86]

According to Ricardo Tatesuzi de Sousa, executive director of ABRANGE (the Brazilian association for producers of non-GE grains), *"In Brazil, it's getting harder for farmers to obtain non-GE soybean seeds."* He says that about 20 per cent of Brazil's soy production is still non-GM, and claims that the biotech companies are dictating what seed growers produce and what seed distributors sell to farmers.[87] In the face of this, the Brazilian agricultural research body EMBRAPA launched the 'Soybean Free' program in 2009, to support farmers to grow non-GM varieties, releasing 35 non-GM soybean varieties.[88] In 2012, EMPRABA calculated that, based on a 1,000 ha soybean crop, non-GM soybeans would save $R 110,000 over GM beans, simply because of not having to pay the technology fee.[89]

GM crops and promised benefits for smallholder farmers

The report of the United Nation's International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) estimates that 40 per cent of the world's population relies on small farms of less than 2 ha of land for their livelihoods.[90] There are more than 500 million of these small farms, occupying about 60 per cent of the arable land worldwide, and they contribute substantially to global farm production. In Africa, 90 per cent of agricultural production comes from small farms.[91] The UN's Food and Agriculture Organization (FAO) states that half of the world's hungry people live in farming households, while another 20 per cent are landless families depending on farming.[92] Biotech companies and the ISAAA have both promoted GM crops as the solution for small holders,[93,94] but the real impact of GM crops on small farmers is hotly contested.

There are growing concerns that GM crops may contribute to small farmers' problems of debt and inequality. The high cost of the seeds, and requirements to protect the intellectual property within GM crops, can put them out of reach for small farmers in the first place.

Furthermore, the reasons for hunger include poverty, lack of necessary infrastructure (such as food storage facilities) leading to losses of harvests and food, environmental and soil degradation, wars, weather problems, and problems relating to market access and access to land.[95] But GM crop technology cannot address any of these problems. Originally designed for industrial farms in North and South America, it is highly questionable whether (and how) small farmers, with their great diversity of food production systems, could actually benefit from them.

High Costs

In South Africa, GM maize appears to have bypassed the majority of small farmers, going instead to the large farmers. A study in 2008, using industry sales data, estimated that around 10,500 South African smallholder farmers bought GM maize seeds.[96] But there are 240,000 smallholder farmers who produce maize for sale in South Africa, and more than two million subsistence farmers.

A detailed study of GM crop adoption by small holders in KwaZulu Natal[97] even had some trouble getting a large enough sample because so few farmers had actually adopted GM crops in the area. 80 per cent of farmers who did not buy Bt maize said it was because the seed was too expensive, and some farmers who had tried out GM herbicide tolerant maize couldn't then afford the associated herbicide. Those who could afford the GM crops ended up increasing their pesticide use. By the end of the study in 2010, it was found that all the farmers who adopted GM crops were growing herbicide tolerant maize, even though they had previously been using non-chemical weeding methods and this did not require their crop to be herbicide tolerant.

In 2010, a report by Traidcraft UK,[98] concerning the use of Bt cotton in Burkina Faso, reported local farmers' concerns that Bt cotton seed was being *"unduly promoted without sufficient regard to the concerns and needs of most farmers."*[99] A 2013 study found that high seed costs were a problem for small farmers in the country, and the risks of GM cotton production were *"disproportionately high"* for resource-poor farmers.[100]

A study examining the potential impact of GM crops in Ethiopia concluded that the technology was likely to be used only by the large, state-owned farms. Small farmers in Ethiopia wouldn't be able to afford the seeds and inputs required for GM seeds, and *"those with big farms will benefit much more than the peasants from GM crops."*[101] It was also noted that small farmers in Ethiopia are concerned about the loss of agricultural biodiversity because of GM crops replacing locally adapted ones.

WEMA (Water Efficient Maize for Africa project)

One of the flagship GM projects aimed at small farmers is Water Efficient Maize for Africa (WEMA). It is a collaboration between Monsanto, BASF and the African Agricultural Technology Foundation (AATF),[102] and is funded by the Gates Foundation. The aim of the project is to create drought tolerant hybrid maize lines, both through genetic modification, conventional breeding and marker assisted breeding. Monsanto and BASF donated licenses for their GM drought tolerance maize lines to AATF for breeding into African varieties,[103] and according to a report by the African Centre for Biosafety, the project is now incorporating MON810 maize into the program, also on a royalty free basis.[104] The first drought tolerant varieties, developed through conventional breeding, were made available in 2013.[105]

WEMA incorporates strong protection for both patented genes and traits developed by conventional breeding. Its intellectual property policy states that *"the technology used in the Project is expected to have considerable commercial value to larger scale farmers in and outside Africa, and the parties also intend to manage Intellectual Property so as to preserve and participate in that commercial value."*[106] Small-farmers will not pay the royalty normally required by biotech companies, but the seed will still be sold under strict licensing conditions, including the use of formal seed distribution networks, 'stewardship' and quality control terms within sub-licenses.[107]

Many smallholder farmers in the target countries are unable to afford certified seed and do not buy seed through seed companies. In Kenya, 80 per cent of farmers save their own seed or get it informally; in Tanzania it is reported that 90 per cent of farmers save seed or acquire it informally;[108] and in Uganda seed companies account for only 15 per cent of seeds planted by farmers.[109] So here again, and because of the desire to protect the intellectual property of the biotech companies, the WEMA project may end up bypassing the small farmers it aims to help. The introduction of Monsanto's Mon810 insect resistant maize into the project also raises the question of whether WEMA represents another route for Monsanto to build markets for its existing GM crops.

BOX 6: A farmer developed alternative: the System of Rice Intensification

The system of rice intensification (SRI) is a production system for rice based on agro-ecological principles. Planting intensity is significantly reduced, irrigation and planting methods aim to increase the vigour of individual plants, and organic matter is added to improve soil condition. SRI originated in Madagascar in the 1980s, and spread initially farmer to farmer. It is credited with improving yields for smallholder farmers across a range of climatic and environmental conditions, and including traditional rice varieties.[110]

A detailed assessment of SRI adoption was undertaken in Mwea, Kenya from 2010 to 2012.[111] Forty of the 50 SRI farmers from 18 sample units showed increases in yields, averaging 1.6 t/ha (33 per cent) while seed requirements were reduced by 87 per cent and water savings averaged 28 per cent. While SRI required 9 per cent more labour costs on average, results were variable, and, in three units, labour costs were reduced by an average of 13 per cent. SRI gave a higher benefit-cost ratio of 1.76 and 1.88 in the first and second seasons, respectively, compared to 1.3 and 1.35 for existing farm practice. The authors also concluded that the net benefits could increase with availability of mechanical weeders and use of organic fertilisation. Finally, they concluded that up-scaling of SRI in Mwea can be expected to help achieve greater national and household food security.

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Losing control and building debt?

In some cases it is not lack of access that is the problem with GM technology for small farmers, but lack of power to make decisions. From the farmer's point of view, the Indian Bt cotton seed market is confusing and unclear, with more than a thousand authorised GM cotton seeds, containing six GM traits often 'stacked' together.[112] Researchers studying villages in Warangal, India, over an 11 year period found that farmers were effectively unable to make informed or evidence-based seed choices.[113] Interviews conducted in 2013 revealed that many village farmers were unaware they were growing Bt cotton seeds, or didn't know if they were or not, even though the only seeds available in the area were Bt varieties. Nor did farmers always know what Bt means, believing it to be a company or brand name.

The researchers pointed out that in the villages they studied, Bt cotton as a technology is *"poorly understood, rapidly changing and difficult to trial."* As a result, meaningful evaluation of Bt cotton seed by local farmers was *"virtually impossible."* Farmers were trapped in a situation where they were unable to make clear judgements on the technology they were being presented with, and in fact the researchers found that much adoption of new GM seed varieties followed local fads, often followed by rapid de-adoption.

In the Philippines, a study of GM maize production was undertaken in 2012 by MASIPAG, a farmer-led network of scientists and NGOs. Covering seven GM maize producing provinces, the study used detailed focus group discussions with GM maize farmers, and 'key informant interviews' with local officials, peasant leaders, agricultural officials, agencies and private companies involved with GM maize.[114] According to the survey, farmers in some areas were unaware that the seeds they were growing were GM maize, and the labelling on seed bags did not make this clear. Farmers stated that they were only told the maize seed was certified hybrid seed, not that it was GM.

A key conclusion of the study was that the weak position of small farmers relative to seed suppliers, traders and financiers, when combined with the higher costs of GM maize production (seed price and herbicides), meant that farmers were more likely to end up in debt to trader-suppliers. Once in debt, they lost control of planting decisions, including whether or not to grow GM maize, potentially driving them further into debt. According to the report, *"GM corn planting is a debt trap for farmers."*

Farmers in the MASIPAG survey also reported that the increased use of herbicides was having an impact on the local environment (such as increasing vulnerability to soil erosion) and also on farmer's abilities to grow other foods. Herbicide sprayed onto GM crops damaged adjacent vegetable and fruit crops, as well as eliminating the possibility of traditional forms of intercropping. It was also suggested that herbicide tolerant crops are encouraging the expansion of cultivated areas onto previously uncultivated uplands, contributing further to erosion and habitat loss.

GM crop technology presents a top down, one-size-fits-all approach for the hugely diverse economic, cultural and environmental situations in which smallholder farmers operate. It is not scale neutral, but appears to favour larger farmers and those with greater capital resources, with the main benefits going to the companies who sell the GM seeds.

What is needed are farmer led, participatory and diverse solutions adapted to local environments, as has been called for by a range of agencies, including the United Nations. A report by the United Nations Special Rapporteur on the Right to Food, based on an extensive review of recent scientific literature, demonstrated that agro-ecological farming systems, if sufficiently supported, can double food production in entire regions within ten years, while mitigating climate change impacts and alleviating rural poverty. Small farmers can double their food production in critical regions by using resource conserving, low external-input techniques. The report calls for a fundamental shift towards agroecology as a way to boost food production and improve the situation of the poorest.[115]

Improving nutrition through GM crops – Golden Rice

Vitamin A deficiency

In 2007, Vitamin A deficiency was estimated to affect 163 million children under five.[116] It is the leading cause of blindness in children, and also impacts on immune function, reproduction and growth, making it a major public health problem for developing countries. The prevalence of Vitamin A deficiency is highly variable,[117] with India having the largest population of Vitamin A deficient children in the world.[118] According to the World Health Organization (WHO), Vitamin A deficiency *"usually ... develops in an environment of ecological, social and economical deprivation,"*[119] and, in terms of addressing this problem, WHO states that *"increasing dietary diversity is generally regarded as the most desirable and sustainable option"* because *"it has the potential to improve the intake of many food constituents – not just micronutrients – simultaneously."*[120]

As long ago as 1992, the UN International Conference on Nutrition recognised that Vitamin A deficiency and its consequences were fully preventable if poor diets could be addressed. The conference recommended that all stakeholders *"ensure that sustainable food-based strategies [diet diversification] are given first priority particularly for populations deficient in Vitamin A."*[121] Supplementation using Vitamin A capsules was considered to be a short term option that should be *"progressively phased out as soon as micronutrient-rich food-based strategies enable adequate consumption of micronutrients."*[122] In 2013, this view was still in force, with the Food and Agriculture Organization (FAO) stating that *"diets that are diverse and environmentally sustainable are the foundation for better nutritional outcomes for everyone and should be a long-term goal for all food systems."*[123]

Golden Rice

It is against this background that GM rice came onto the world stage. In 2000, Professor Ingo Poytrickus found himself in the spotlight because of his work on a new genetically modified rice with enhanced pro-vitamin A content. Ingo Potrykus's aim was to produce biofortified rice as an aid to combatting Vitamin A deficiencies in areas where rice is the staple food. Time Magazine reported that the new GM rice — dubbed 'Golden Rice' — *'could save a million kids a year.'*[124]

Golden Rice has been genetically modified to biosynthesise beta-carotene, a precursor of Vitamin A, in the edible parts of the grain. The modification also leads to a colour change in the grains, hence the name Golden Rice. The original developers of Golden Rice transferred intellectual property rights to the biotech company Syngenta, which then donated all legal rights to the Humanitarian Board of the Golden Rice Project with the aim that seeds would be made freely available to farmers earning below US$10,000 per year. Syngenta retained the rights to the GM rice in developed countries, but stopped commercial development in 2006, reportedly due to low returns on investment.[125]

Some of the main donors to the Golden Rice project include the Rockefeller Foundation, the Bill & Melinda Gates Foundation (through their Grand Challenges in Global Health Initiative), USAID, HarvestPlus, the European Commission, Swiss Federal Funding, and the Syngenta Foundation.[126] Members of the project's 'Humanitarian Board' include representatives from USAID, the Rockefeller Foundation, the International Rice Research Institute (IRRI) and former employees of Syngenta. USAID was one of the donor countries most supportive of the use of Vitamin A supplementation to tackle Vitamin A deficiencies in developing countries.

The Golden Rice Project does not claim to be the magic bullet against malnutrition, and very importantly, they themselves recognise that their approach is not the best means of tackling malnutrition:

"The best way to avoid micronutrient deficiencies is by way of a varied diet, rich in vegetables, fruits and animal products. The second best approach, especially for those who cannot afford a balanced diet, is by way of nutrient-dense staple crops."[127]

But they go on to state that:

"Biofortified crops, like Golden Rice offer a long-term sustainable solution [to Vitamin A deficiency], because they do not require recurrent and complicated logistic arrangements once they have been deployed."[128]

However, IRRI has recognised that *"it has not yet been determined whether daily consumption of Golden Rice does improve the vitamin A status of people who are Vitamin A deficient and could therefore reduce related conditions such as night blindness."*[129] In order to determine this, and if approved by national regulators, the initiative will cooperate with Helen Keller International and other partners to conduct *"a controlled community study to ascertain if eating Golden Rice every day improves vitamin A status."*[130]

two What the GM industry won't tell you

continued

Moves to introduce Golden Rice

In 2011, the International Rice Research Institute (IRRI) received a US$10.3 million grant from the Bill & Melinda Gates Foundation to develop Golden Rice varieties in the Philippines and Bangladesh.[131] Possible commercial introduction of Golden Rice by IRRI in the Philippines was originally estimated to be around 2011,[132] but this has not yet happened. However, in February 2013 it was announced that the Philippine Rice Research Institute had just finished two seasons of field trials of Golden Rice.

The prioritisation of this costly research in the Philippines is surprising, given that there have already been successful programmes to reduce Vitamin A deficiency in that country. According to the Filipino Food and Nutrition Research Institute (FNRI) of the Philippines' Department of Science and Technology, the prevalence of Vitamin A deficiency among children declined from 40.1 per cent in 2003 to 15.2 per cent in 2008, and there was a reduction to mild deficiency among pregnant and lactating women.[133] However, the Philippines is one of the few countries in Asia which already has GM crop production.

Public concerns about Golden Rice

A number of concerns have been raised about the potential health impacts and effectiveness of Golden Rice, mainly by civil society organisations.[134] There is also a high risk of GM contamination of non-GM rice varieties, because most rice is produced by small-scale farmers, who often share seeds.[135] In addition, according to NGOs in the region, most of the work on Golden Rice to date has been done on japonica rice varieties, which do not grow well in Asian fields, while the people that are being targeted by the project mainly eat indica rice varieties.[136] There is also a lack of basic data, such as content of beta-carotene at harvest, after storage and cooking.[137]

There is public concern about Golden Rice in Asia. Opposition to the authorisation of any GM food crops has been expressed by the governments of at least seven Indian states.[138] In China, Golden Rice has been the subject of public scandal after a US university admitted that it had conducted feeding trials on schoolchildren without their parents' informed consent.[139] Golden Rice is also an issue of hot debate in the Philippines,[140] and in 2013 Golden Rice field trials in the Philippines were destroyed by the Peasant Movement of Bicol and the Sikwal-GMO alliance.[141] Although this was an act of criminal damage, a statement in support was signed by farming and civil society groups from Thailand, India, South Korea, Vietnam, Japan, Nepal, Sri Lanka, Mongolia, Indonesia, Cambodia, Bangladesh, Iran, Malaysia, Ghana and the United States.[142] They commented that *"local communities have the legitimacy and the right to say no to GE crops like Golden Rice and defend their health, environment, territories and livelihoods."*

No to commercial GM rice

GM rice has not gone into commercial production in any of the major rice producing countries, including China[143] and Thailand.[144] In 2011, it was reported in Chinese media that *"the government will not promote the commercialization of genetically modified rice and wheat for five to ten years"*[145] because of concerns about the safety of genetic modification, and that the relevant research, promotion, and regulatory protections were not sufficiently developed for GM rice to be put into commercial production.[146]

In fact, Iran is the only country to have cultivated GM rice on a commercial basis. But in 2006, after only one year of production, cultivation was suspended on the grounds that there had been insufficient consultation with other government ministries.[147] In the same year, genetic material from a GM herbicide tolerant rice, which was being grown in field trials in the United States (LibertyLink rice LLRICE62), was detected in US rice exports to several continents.[148] The rice was subsequently approved for food purposes in the USA, but not for cultivation.

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conclusion: Sustainable solutions to tackle hunger

Those calling for a new Green Revolution argue that what is needed to tackle hunger is more intensified agriculture, which relies heavily on increasing use of non-renewable resources such as fertilisers and fossil fuels. This is despite mounting evidence that industrial agriculture is destroying the resource base on which we rely to produce food. It has degraded soils, contributed to greenhouse gas emissions[1] and decreased agricultural biodiversity.[2] Genetically modified crops are still a model developed for use in industrial agriculture systems. Nearly 100 per cent of the GM crops in use today are designed to simplify and reduce the need for careful monitoring of pesticide application. Evidence from a few decades of the use of these crops in North and South America show that they have increased pesticide use due to weed and insect resistance – and therefore HT and BT GM crops are not a solution to dealing with pests. In addition, given emerging evidence of the negative impacts of pesticides on the environment and health, these GM crops are no longer fit for purpose. As this report shows, despite a great deal of publicity about the success of GM crops across the globe, there is significant resistance to them in all continents. GM crops are planted on a small area of global arable land, and have been taken up by less than one per cent of the world farming population. In addition, claims that there is scientific concensus on the safety of GM crops is not true — on the contrary there is growing evidence of harm, especially due to the use of pesticides on GM crops.

In the last few years, the focus of publicity for GM crops has once again turned to Africa, where we are promised they will solve nutritional deficiencies by adding nutrients to crops and solve hunger by increasing yields. Yet these approaches are questionable for a number of reasons. Tackling hunger has more to do with improving access to and redistribution of food than simply producing more food, as evidenced by the fact that we already consistently produce enough calories to feed an estimated nine billion people.[3] However over half of cereals produced globally go towards feeding livestock in intensive systems rather than humans. The United Nations Environmental Programme (UNEP) estimates that, even accounting for the energy value of the meat produced, the loss of calories that result from feeding cereals to animals instead of using cereals directly as human food represents the annual calorie need for more than 3.5 billion people.[4] In addition approximately 1.3 billion tons of food produced for human consumption – about one third of the total – is lost or wasted.[5] Of the remaining, increasingly food crops are being diverted to produce biofuels which is raising food prices and taking over precious land.[6]

As regards malnutrition, as with most problems that GM methods are trying to fix, the causes of malnutrition are multiple and complex including a lack of varied diets, and inadequate consumption of nutrient-rich foods such as meat, eggs, fish, milk, legumes, fruits and vegetables. Moreover, the problem is made worse by inadequate health care and sanitation, disease, and a lack of education in infant- and child-care.[7] Some of the most influential actors in the malnutrition debate like USAID and World Bank, Global Alliance for Improved Nutrition and the Micronutrient Initiative recognised in 2009 that the main avenue towards tackling hidden hunger was diet diversification, however this was considered by them a *"complex and long-term undertaking."*

"Quality, varied diets would resolve most vitamin and mineral deficiencies. However, improving the diets of the world's poor is a complex and long-term undertaking that is largely dependent on rising incomes, improved access to food, better health and nutrition services delivery, and changing infant and young child feeding practices".[8]

It is important to acknowledge that nobody disagrees that diet diversification is the long-term and most sustainable strategy to tackle malnutrition. It is far from proven that GM crops gives results faster and more effectively than diet diversification strategies – with all publicity and reports continuing to discuss the potential of these crops rather than any available and proven solutions.[9]

At the same time there is growing evidence from around the world of techniques and experiences that show how agriculture can be developed sustainably, guaranteeing food sovereignty or safe, healthy, varied and culturally appropriate food for everyone while respecting and developing the role of small holders. The main such approach, agroecology, is both a science and a set of practices, as well as a social and political movement.[10]

As a science, agroecology is the *"application of ecological science to the study, design and management of sustainable agroecosystems."*[11] As a set of agricultural practices, agroecology seeks ways to enhance agricultural systems by mimicking natural processes, thus creating beneficial biological interactions and synergies among the components of the agroecosystem.[12]

It is based on practices such as recycling biomass, improving soils with green manures, and bio-fertilisers, minimizing water, nutrient and solar radiation losses, intercropping, mixed farming with a variety of crops and farm animals, and minimising the use of chemical fertilisers, herbicides and pesticides. Agroecology is highly knowledge-intensive, based on techniques that are not delivered top-down but developed on the basis of farmers' knowledge and experimentation.

Agro-ecology has moved beyond the field to agroecosystem scales where its defining feature is dramatic improvements in productivity over space and time in agricultural systems as a whole rather than in just one species. This tends to also provide other benefits such as diversified income streams, risk management for crop failures and varied produce that can

improve diets. It has also moved towards a larger focus on the whole food system, defined as a global network of food production, distribution and consumption.[13] Academics understand agroecology as an interdisciplinary approach, that includes the social and human sciences as well as the ecological and agricultural sciences, using methods and approaches from various disciplines, and taking into account local knowledge.[14, 15]

As a way to improve the resilience and sustainability of food systems, agroecology is now supported by an increasingly wide range of experts within the scientific community.[16, 17, 18]

For instance, yields of rice, one of the most important staple foods globally, have been transformed in many developing countries through the use of the System of Rice Intensification, (SRI). This is an agroecological farming method[19] which increases the productivity of irrigated rice by managing the relationship between plants, the soil, water and nutrients. It was devised in the 1980s and has been demonstrated in over 50 countries, where results have seen from between 20-100 per cent or more in increased yields, a reduction of up to a 90 per cent in required seed, and up to a 50 per cent reduction in water use.[20]

The UN Special Raporteur on the Right to Food has reported that it has the potential to double food production in critical regions in ten years.[21] The United Nations Trade and Environment Review 2013 has said, [the world needs]

"a rapid and significant shift from conventional and monoculture based and high external input dependent industrial production towards mosaics of sustainable and regenerative production systems that also considerably improve the productivity of small scale farmers. We need to move from a linear to holistic agricultural management."[22]

Agro-ecologists question the dominant agronomic model based on the intensive use of external inputs and criticise the impacts of agricultural industrialisation.[23] On these grounds they also question the wisdom of the so-called Second Green Revolution proposed for Africa. Despite hundreds of successful examples of agroecology worldwide the best options are simply not being promoted sufficiently by leaders at the highest political levels.[24, 25] There are cheaper, better and readily available solutions to address hunger and malnutrition than GM crops. Most of these can be implemented immediately by governments around the world with political will, and they include:

- *Stopping the large amounts of crops and land diverted from food to agrofuels production*
- *Introducing measures to reduce high levels of consumption of livestock products in industrialised countries that are sucking up global grain supplies*
- *Reducing high levels of retail and household waste in industrialised countries and post-harvest loss in the developing world*
- *Build capacity to produce food for local consumption rather than for export, with an emphasis on small-scale food producers.*

Scale up investment in agro-ecology including:

- *In participatory research that uses traditional knowledge of small holders and combines it with modern approaches*
- *In enabling development and access to low cost traditional varieties of seeds led by local communities and livestock breeds and increases agricultural biodiversity*
- *By providing agricultural extension services so farmers can access and implement knowledge that will enable them to farm more sustainably, and ensure that farmers are involved in developing research programmes*
- *By supporting the establishment of farmers' cooperatives and other producer organisations for small holders and ensuring local and national markets can work for smallholders*

footnotes

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