DISPELLING THE MYTHS

THE REAL FACTS ABOUT AGRICULTURAL BIOTECHNOLOGY AND BIOTECH FOOD

USSEC
U.S. SOYBEAN EXPORT COUNCIL
16305 Swingley Ridge Road
Suite 200
Chesterfield, MO 63017–USA
phone: 636.449.6400
fax: 636.449.1293
www.ussec.org

ASA International Marketing
USB United Soybean Board

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Executive summary

After 17 years' experience in the commercial production of biotechnology crops, by 2013 more than 18 million farmers across 27 countries find that the technology works as a highly successful farm tool delivering tremendous environmental and safety benefits.

Over the past 17 years, millions of consumers across the world have eaten foods made or derived from biotech crops with no identified health problems. Overall, the environmental benefits through reduced fuel use, reduced greenhouse gas emissions and reduced land erosion have benefited society as a whole.

Despite the wealth of scientific evidence and practical experience supporting all the above, some people remain unconvinced of the benefits and are opposed in general to the application of biotechnology in food production. Perversely, the use of biotechnology in healthcare has suffered little to none of the attention compared to that focused on agriculture. For example, recombinant DNA technology offers safer and more efficient ways of producing insulin and blood-clotting proteins and the resultant products are used by millions of people worldwide.

This paper – *Dispelling the Myths* - is an update of an earlier version and shows, that despite the manufactured controversy over agricultural biotechnology the benefits continue to accumulate.

More and more farmers across the world are turning to the technology every year. The reason is simple: they find that it works and that it is scale neutral bringing benefit to small and large farmers alike. For example, when biotech, insect resistant cotton was first grown in India in 2002 it was grown on 49,978 hectares (123,500 acres). In 2013, more than seven million Indian farmers grew Bt cotton on more than 11 million hectares (27.2 million acres) – which represents 95% of total Indian cotton production. The average field size is 1.5 hectares (3.7 acres).

In summary, the evidence shows that agricultural biotechnology:

- Delivers multiple benefits. It has raised farmer incomes, saved them time, reduced their input costs, and enhanced their competitiveness.

- Has helped to reduce yield losses due to weeds and insect pests.

- Has reduced chemical use and substituted environmentally harmful chemicals with more benign herbicides.

- Has enabled greater use of conservation tillage, reduced soil erosion, and cut the amount of CO_2 farming releases into the atmosphere.

- Has proven to be advantageous for farmers in developing countries by allowing increased yields and reductions in the use of toxic chemicals.

- Has helped to reduce the risk of mycotoxin contamination in maize (corn), a serious problem in many developing countries.

- And finally, the technology has been confirmed as safe as conventional crops by the world's leading scientific institutions and authorities with not a single verified incident that biotech crops cause harm to the environment, human or animal health.

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U.S. Soybean Export Council
16305 Swingley Ridge Road
Chesterfield, MO 63017, USA
T: +1-636-449-6400 & F: +1-636-449-1923
www.ussec.org
www.ussoy.org

	The United Soybean Board (USB) is a checkoff (or levy) board supported by more than 590,000 registered U.S. soybean farmers who contribute 0.5 percent of the market price of their soybeans at the first point of sale. These funds are managed by the USB farmer directors to facilitate market creation, market research and commercialization programs. The USB is composed of 69 volunteer farmer-leaders appointed to the Board by the U.S. Secretary of Agriculture. www.unitedsoybean.org

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Safety and health

Myth 1: Biotech food is inherently unsafe and untested and has harmed hundreds of consumers.

Reality: Crops and foods improved through biotechnology are at least as safe as those produced through other methods. This has been confirmed by every competent body that has considered the issue.[1] Indeed, the only time a safety differential has been confirmed it has found the biotech crops and foods safer.[2] Agricultural biotechnology allows very precise plant breeding. The technology has contributed significantly to reduce the amount of pesticides used by farmers and also to reducing the amount of toxins and food allergens in the food supply. Biotechnology makes possible the development of new diagnostic techniques to detect allergens present in foods, and therapeutic interventions to prevent sensitive individuals from reacting if they are inadvertently exposed to an allergen.

Consumers worldwide have been eating biotech crops in many forms since 1997 with no sign of any health or safety problems.[3] This observation is consistent with the numerous peer reviewed studies on the safety of biotechnology crops for humans, animals and the environment.[4]

In the EU, which has experienced the heights of consumer anxiety, the European Commission has funded more than 130 studies on the safety of biotech crops covering more than 300 research groups over a period of 25 years.[5] One such study, by the European Commission's Joint Research Centre in 2008, concluded:

> "There is a comprehensive body of knowledge that already adequately addresses current food safety issues including those dealing with GM products; it is considered by the experts as sufficient to assess the safety of present GM products."[6]

In July 2012, the EU's Chief Scientist Professor Anne Glover said in an interview:

> "There is no substantiated case of any adverse impact on human health, animal health or environmental health, so that's pretty robust evidence, and I would be confident in saying that there is no more risk in eating GMO food than eating conventionally farmed food."[7]

In August 2012, a report by the Swiss National Science Foundation at the request of the Swiss Federal Council concluded that:

"......Based on long term observations and many scientific studies, no negative health effects from commercially used GM Crops are verifiable". "The use of Bt maize can have positive health effects. It can lead to a lesser contamination of food and feedstuffs by neurotoxic or cancerogenous mycotoxins".[8]

Safety concerns are fundamentally based on the belief that biotechnology methods for introducing traits into plants might somehow be riskier than so-called "traditional plant breeding methods". But this misapprehension has been rejected repeatedly by authoritative scientific bodies[9]. Also, the chief scientific adviser of the United Kingdom has stated:

> "...because the technique is so sophisticated, in many ways it is probably safer for you to eat GM products - plants that have been generated through GM - than normal plant foods, if you have any sort of reaction to food, because you can snip out the proteins that cause the negative reaction to certain parts of the population."[10]

The German Academy of Sciences has found:

> "...in consuming food derived from GM plants approved in the EU and in the USA, the risk is in no way higher than in the consumption of food from conventionally grown plants. On the contrary, in some cases food from GM plants appears to be superior in respect to health."[11]

Biotech allows greater precision, predictability, and thus safety assurance than traditional plant breeding thus allowing a considerable increase in safety checks. For example, during the 1960s, a new potato variety (Lenape) was developed using traditional plant breeding methods that contained a near-lethal level of solanine, a natural alkaloid toxin. In the 1980s, a celery variety was developed, also using traditional plant breeding methods that contained high levels of psoralen, a natural toxin that is a skin irritant and had been shown to cause cancer in laboratory mice. Before it was withdrawn from the market, field workers who picked that celery crop suffered great pain in the skin of their hands.

Both of these incidents occurred because traditional plant breeders crossed domesticated crop varieties with their wild relatives in order to introduce certain desirable traits (e.g. disease resistance, higher yield, etc.) into the crop gene(s). Also see *Safety of Genetically Engineered Foods: Approaches to Assessing Unintended Health Effects* (2004).[12]

Because such a cross is a mixture of the genes from both plants, the resultant offspring plants can also inherit undesirable traits from their parents. Due to that fact, the U.S. government's Food and Drug Administration (FDA) requires testing of new crop varieties for the presence of such toxins, whether the new variety was developed through biotechnology methods or "traditional plant breeding methods".[13]

The FDA's requirements, coupled with the potential for financial liability, has ensured that seed companies planning to introduce a new biotechnology-derived event in the U.S. also thoroughly test all newly introduced proteins for allergenicity.[14] But it is not only the U.S. that carries out such stringent assessments of biotechnology foods and crops. Regulatory agencies worldwide will ensure that biotech foods and crops have gone through onerous scientific and technical assessment before being authorized for commercialization. This ensures that potential safety issues are identified.
For example, one seed company had begun work using biotechnology methods to develop a soybean variety that would contain a gene from the Brazil nut tree (to impart a higher methionine content), but all work on that new soybean variety was halted when allergy testing indicated that it could trigger reactions in consumers who are allergic to Brazil nuts.[15] As referenced above, this is a prime example of how biotechnology allows for enhanced detection of allergens.

Despite this overwhelming preponderance of authoritative scientific approval of both the biotechnology process and its products, professional protest groups continue to raise alarms impugning their safety.[16]

Yet not all campaigners cling to ideological beliefs when confronted with the facts. Stewart Brand, Editor of the *Whole Earth Catalogue* said:

> "I daresay the environmental movement has done more harm with its opposition to genetic engineering than with any other thing we've been wrong about.....We've starved people, hindered science, hurt the natural environment and denied our own practitioners a crucial tool."[17]

And Mark Lynas writing in the UK's *New States*man magazine stated:

> "Genetic engineering, on the other hand, was something I spent years of my life campaigning against. And yet here, too, a science-led assessment of the likely risks and benefits suggests that I was wrong".[18]

In a major report, *Planting the Future: opportunities and challenges for using crop genetic improvement technologies for sustainable agriculture,* published by the European Academies' Science Advisory Council in 2013, one of the conclusions stated:

> "There is no validated evidence that GM crops have greater adverse impact on health and the environment than any other crops developed by alternative technologies used in plant breeding. There is compelling evidence that GM crops can contribute to sustainable development goals with benefits to farmers, consumers, the environment and the economy."[19]

Perhaps the American Medical Association summed it up most succinctly:

> "Attempts to introduce GM foods have stimulated not a reasoned debate, but a potent negative campaign by people with other agendas. Opponents ignore common farming practices and well-investigated facts about plants, or inaccurately present general problems as being unique to GM plants."[20]

Myth 2: U.S. consumers do not eat genetically engineered soy and corn products because these crops are exported to China and other countries.

Reality: Untrue.

Soy and corn products developed by biotechnology have been consumed by U.S. consumers since 1997 in many food products. In 2012, nearly 94% of total U.S. soy production of 82 million metric tons (MMT) was from biotech soybeans. More than half of this production – 54.4 MMT - was consumed in the U.S. mainly through poultry feed (49%) and pig feed (26%) with the rest used in other animal feedstuffs and human food. The remaining 36.6 MMT was exported to 38 overseas countries, including China and the European Union. There is no separation of soybeans for domestic or export use – they are all just soybeans.

The fact that biotech foods and crops are consumed in the U.S. with no substantiated issue is underlined in a report from the United Kingdom's Council for Science & Technology which in a section on the safety of biotech crops stated …. *"Notably, even in the highly litigious USA, there have been no successful lawsuits, no product recalls, no substantiated ill effects, and no other evidence of risk from a GM crop product intended for human consumption since the technology was first deployed commercially in 1994."*[21]

Further, a 2012 survey of U.S. consumers for the International Food Information Council (IFIC) showed that 30 percent of those surveyed believed foods produced from biotechnology were available in food supermarkets and that more than 70 percent said they were likely to "purchase foods produced through biotechnology to provide more healthful fats like omega-3s".[22]

Aside from the U.S., other major soy exporting countries also do not differentiate between what is consumed domestically and what is exported to other countries. For example, the total soy production in Brazil in 2013 was 89% biotech and in Argentina it was 99%. Both countries exported nearly half of their production to many overseas countries including China and the European Union. For more information see www.soystats.org.

Myth 3: Soy allergies have increased because of biotech soybeans.

Reality: Untrue.

This myth continues to surface and appears to be based on a report in a British newspaper, the *Daily Express*, in 1999. The source of the claim – an allergy testing center in York in England - issued a statement pointing out that it did not say soy allergies had increased because of biotech varieties, but that it had more customers who had soy allergies, which if accurate, was probably due to the increased consumption of soy in modern food (soy is a well-known allergen).

There is no evidence that biotech soy increases the risk for soy-allergies in any way. Instead, biotechnology can help to remove dangerous allergens from food. In fact, biotech foods are less likely to be allergenic than any others. In contrast to all other foods, those derived through biotechnology are routinely screened in advance to ensure they contain no DNA similar to sequences known to encode for allergenic proteins.

Furthermore, biotech researchers are pursuing a variety of approaches intended to remove the allergenicity of common foods today threaten people with food allergies. Researchers are working to eliminate from soybeans the gene encoding the allergenic protein to which some are sensitive.[23] Scientists are similarly working to delete similar genes encoding allergenic proteins from peanuts,[24] milk and other foods.

Myth 4: Biotech crops increase antibiotic resistance.

Reality: Research regarding the development of antibiotic-resistant bacteria in humans from "marker genes" (used in a few of the early commercialized biotech crops) overwhelmingly proves the near impossibility of such resistance occurring.

In June 2009, the European Food Safety Authority (EFSA) published a report which provided a consolidated overview of the use of antibiotic resistance marker genes in biotech plants. The report included a joint scientific opinion of EFSA's GMO and BIOHAZ panels. The panels concluded that no new scientific evidence has become available that would prompt EFSA to change its previous opinions on these GM plants.[25]

Over-prescribing (i.e. excessive therapeutic use) of a particular commercial antibiotic is the proven source of such antibiotic-resistant pathogenic bacteria.[26],[27] To test whether "marker genes" also could possibly be a source of antibiotic-resistant pathogenic bacteria, scientists in the United Kingdom attempted to cause antibiotic resistance in bacteria within an "artificial cow stomach" in a carefully controlled laboratory experiment by adding to the artificial stomach biotechnology derived corn that contained an antibiotic-resistance "marker gene" within its DNA.[28]

Transfer of antibiotic resistance from that corn to the bacteria growing within the "artificial cow stomach" did not occur in 10^{18} (i.e. 1,000,000,000,000,000,000) generations of the bacteria under conditions that were designed to make that transfer as likely as possible.[29]
Therefore, the probability for such transfer of antibiotic resistance occurring (e.g. from Bt corn to bacteria) is even less likely than 1 in 10^{18} (i.e. 1 out of 1,000,000,000,000,000,000). The odds are small to say the least and amply proven to be a smaller cause of transfer than through the route of over-prescription of commercial antibiotics.

In contrast, the natural bacteria living within human digestive systems have already been shown to exhibit resistance to the relevant commercial antibiotics (i.e., kanamycin and ampicillin) in 20% of typical humans.[30]

All this has been repeatedly confirmed in subsequent experiments where biotech crops with antibiotic marker genes were fed to chickens. No plant-derived marker was found in the intestines, let alone surviving to be transformed into ampicillin resistance.[31] The Working Party of the British Society for Antimicrobial Chemotherapy reported that it could find "no objective scientific grounds to believe that bacterial antibiotic resistance genes will migrate to bacteria to create new clinical problems."[32]

Finally, in *Tomorrow's Table: Organic Farming, Genetics and the Future of Food* Professor Pamela Ronald at the University of California, Davis answered the question on whether or not antibiotic resistance genes are somehow acquired by the bacteria that live in our intestines, stated:

> "'According to a committee of the National Academy of Sciences, this is unlikely. First the gene would have to escape the human digestive juices, then it would have to survive intact in the human gut and finally it would have to move into the intestinal bacteria. Indeed, one study showed that transgenes in GE soy are completely degraded by the time they get to the large intestine (Netherwood et al. 2004). Furthermore, many antibiotic resistance genes are already common in bacteria and have been found in our food all along. There are also many technological advances that make [Raoul's] concern even more remote. For example, new markers, such as sugar enablement markers are now available, so antibiotic resistance genes are being used less often. Also, many new transgenic crops, such as Xa21 rice that is resistant to bacterial disease, do not contain marker genes at all'".[33]

Myth 5: Biotech crops are making food less safe.

Reality: Biotech crops are making food safer, by reducing pesticide residues and, in the case of Bt maize (corn), by reducing mycotoxin contamination.

The Union of the German Academies of Science and Humanities' Commission on Green Biotechnology reported, "food from biotech corn is healthier than from conventionally grown corn."[34] It made this statement because investigations have shown that contamination of maize (corn) by the carcinogenic fungal toxin, fumonisin, is reduced in biotech insect-resistant Bt corn.

The German Commission also stressed that the potential for unintentional DNA mutations is much higher in the process of conventional plant breeding, using mutagenic chemicals or ionizing radiation, than in the generation of biotech plants. Furthermore, biotech products are subject to rigid testing with livestock and rats before approval, unlike conventional or organic varieties.

The enhanced safety advantages of insect resistant maize (corn) were further supported by former Italian Minister of Health and one of the world's leading oncologists, Professor Umberto Veronesi, who stated in an article in *La Repubblica* that:

> "Genetically modified maize is attacked much less by the European corn borer than conventional maize. This is why I am against the unconceivable demonizing of GMOs and I am completely in favor of using them, when there is a clear advantage for human health. For the future I am therefore convinced that with the techniques already available to researchers, it is possible to obtain better quality food production, a higher protection from toxic agents and a higher level of security for consumers."[35]

The importance of reducing fumonisin levels cannot be over-emphasised. Fumonisin is a mycotoxin, a neurological poison released by fungi of the genus *Fusarium*, a common grain mold which grows inside food plants, either due to poor storage or to insect damage that provides entry for the fungal spores.

In countries with modern agricultural systems, regular testing, good dry storage and judicious use of chemicals keeps mycotoxins to a minimum. In developing countries, where none of these things happen reliably, mycotoxins can be a serious hazard. In Guatemala and elsewhere, babies, born to women who eat large amounts of infected maize (corn), suffer neural tube defects at rates six times higher than the global average.[36]

Bt maize (corn) is a powerful and effective way to reduce fumonisin to a safe level without chemicals. Its built-in pesticide against the corn borer greatly reduces plant damage, and thereby removes most of the risk of fungal spores getting inside before processing.[37]

In testimony to the U.S. House of Representatives, Dr. Roger Beachy, President Emeritus Donald Danforth Plant Science Center, said:

> "...... we have seen some of the well-known risks of conventional or organic agriculture dramatically reduced: the potential for contamination of food with cancer-causing compounds like aflatoxin in corn has been dramatically reduced through biotechnology; exposure of farmers to potentially dangerous neurotoxins used to control pests has been dramatically reduced, as have been the cases of unintentional exposure with all their health consequences; the quality of runoff from agricultural lands has improved with the widespread adoption of biotech crops as no-till methods of weed control, as carbon sequestration in soils and greenhouse gas emitting consumption of fossil fuels have been significantly reduced".

And in his concluding comments, Dr. Beachy stated:

> "[through]....the use of terminologies that falsely imply risk and potential lack of safety, we have created the perception that the technology itself is unsafe and that products derived from the technology are therefore unsafe. Scientific consensus over the past 20+ years has indicated otherwise".[38]

However, specific myths that continue to be recycled by diehard opponents include the claim that biotech potatoes or soybeans have been shown to be unsafe. The potato claim originates in a media interview given by Scottish researcher Arpad Pusztai. A much reduced set of claims was made in a paper subsequently published, amidst controversy (against the advice of the peer-reviewers). Although the British Royal Society found that multiple failures in experimental design and execution make it impossible to draw any firm conclusions from Pusztai's research on this topic, in the end it appears that he actually showed little more than the unremarkable and well known fact that a steady diet of potatoes is not adequate to ensure optimum health in rats.[39]

Elsewhere, Russian scientist Irina Ermakova gained a measure of notoriety with her claims, announced in a press conference sponsored by Greenpeace, that biotech-improved soybeans fed to rats resulted in increased mortality and decreased fertility. Ermakova's claims have not been published in a peer reviewed paper in the scientific literature. However they were examined in a special feature in the journal *Nature Biotechnology*[40] The verdict is that Ermakova's claims fail on multiple counts: she fed her rats a diet that had an unquantified mixture of biotech and conventional ingredients; she failed to demonstrate any dose/response in her experimental animals; her control animals showed mortality and infertility at rates significantly in excess of what would be expected under proper husbandry. However, the study also provoked global condemnation by scientists and food safety agencies which vehemently rejected the study as poor science and invalid research. The best overall rebuttal of Ermakova's study is that by Dr. Nina Fedoroff.[41]

As egregious are the above examples, another issue of poor science being exploited by activists and the media is a study published in September 2012 in *Food and Chemical Toxicology* by French molecular biologist Giles-Eric Séralini. The study claimed that rats fed on a diet of glyphosate-resistant maize NK603 (corn) and with glyphosate added to their water developed more tumors and died sooner than their controls.

The study was greeted with strong condemnation for being seriously flawed and inadequate by scientists across the world. A number of EU national food safety agencies (Germany, Belgium, and the Netherlands) also joined the criticism. An initial review by the European Food Safety Authority (EFSA) stated that the study was "of insufficient scientific quality for safety assessment".[42]

The Brazilian National Technical Commission on Biotechnology (CTNBio) in its own report also condemned the study for failing to provide solid and complete information.[43] And in an extremely rare event in French science a statement was issued by the national academies of agriculture, medicine, pharmacy, sciences, technology and veterinary studies which stated that "this work does not enable any reliable conclusion to be drawn," adding bluntly that it only helped "spread fear among the public."[44]

The academies went further, stating:

> "Given the numerous gaps in methods and interpretation, the data presented in this article cannot challenge previous studies which have concluded that NK603 corn is harmless from the health point of view, as are, more generally, genetically modified plants that have been authorised for consumption by animals and humans".

Soon after the academies statement, the French High Council on Biotechnology (HCB) and the French national food safety agency, ANSES, issued their own reviews which also criticized severely the Seralini study. The HCB concluded:

> "...The reporting of the results is fragmentary and imprecise. Only some results are selected, reported or commented on; the reporting of these selected results lacks precision and biological relevance and uses nonconventional 'nomenclature'.
> This imprecise and fragmentary description forms the basis for unproven conclusions, which are then used to construct unjustifiable pathophysiological hypotheses."[45] [46]

Finally, in November 2013, the publisher withdrew the study[47] and it has not been defended by any credible scientists, and has not been repeated.

More recently, one of the largest assessments ever conducted was published[48] confirming the safety and superiority of animal feed derived from biotech crops. Researchers evaluated the results from more than 100 billion animals fed biotech derived feed over 19 years in trillions of meals. Not only did this observational study find no ill effects, but the average health of the animals was seen to improve over this time span. The result is that we now have multiple large sets of data

> …both experimental and observational, showing that genetically modified feed is safe and nutritionally equivalent to non-GMO feed. There does not appear to be any health risk to the animals, and it is even less likely that there could be any health effect on humans who eat those animals.
>
> In order to maintain the position that GMOs are not adequately tested, or that they are harmful or risky, you have to either highly selectively cherry pick a few outliers of low scientific quality, or you have to simply deny the science.[49]

At the end of the day, the fact remains: crops and foods improved through biotechnology have been subjected to more scrutiny, in advance, in depth and detail than any others in history. Without exception, they have been found to be as safe as, if not safer than, their conventional or organic counterparts.

Myth 6: Agricultural biotechnology offers no direct benefits to consumers.

Reality: The next generation of biotech soybeans has already begun to deliver direct consumer benefits through improved vegetable oil profiles, and benefits will increase in coming years.

Aside from the obvious societal benefits to the planet of reduced chemical use, lower carbon greenhouse gas emissions and safer crops, agricultural biotechnology has moved beyond input traits and is on the verge of delivering a number of varieties with direct consumer benefits by 2015-16.

Such beneficial traits include lower saturated fat, increased isoflavone content and increased omega-3 fatty acids. Scientists in the United Kingdom report that biotech crops are an excellent, sustainable way to add sufficient omega-3 into the food chain without damaging increasingly fragile fish stocks[50].

Other new varieties will offer the availability of 50 percent more iron in the diet which will help consumers with anemia (the United Nations estimates 1.62 billion people worldwide are iron deficient[51]; high oleic acid soybeans which were planted in the U.S. for the first time in 2012 will eliminate the need for hydrogenation of soybean oil – a process which introduces trans fats.

Researchers are working to develop a new high beta-conglycinin soybean, which will provide soy protein with better taste, texture and ability to blend with foods. Beta-conglycinin is a naturally occurring, texture- and flavor-improving compound. The new soybean variety will also contain more soluble protein than any other soy protein on the market.[52] This soybean is being developed through conventional breeding, but in the U.S. it will be genetically modified for herbicide resistance.

It is however substantially misleading to claim an absence of 'consumer benefits' from biotech crops placed on the market to date as some anti-biotech campaigners are prone to do. The reality is that all consumers live in the environment; and the environmental benefits of cleaner, higher quality and safer harvests produced using less water, less chemicals and less diesel fuel as well as substantial reductions in topsoil loss and greenhouse gas emissions benefit consumers around the globe.

This is best summed by the European Commission report *A Decade of EU-funded GMO Research (2001-2010)* which concluded:

> "……Biotechnologies could provide us with useful tools in sectors such as agriculture, fisheries, food production and industry. Crop production will have to cope with rapidly increasing demand while ensuring environmental sustainability.
>
> Preservation of natural resources and the need to support the livelihoods of farmers and rural populations around the world are major concerns. In order to achieve the best solutions, we must consider all the alternatives for addressing these challenges using independent and scientifically sound methods. These alternatives include genetically modified organisms (GMO) and their potential use." [53]

Myth 7: Farmers and biotechnology companies are opposed to mandatory labels for "GM" foods because they are trying to hide safety concerns from consumers and deprive them of freedom to choose.

REALITY: Consumers who wish to avoid biotech foods already have a label *("Organic")* they can use to avoid biotech if they wish. As already referenced above, biotech foods would not appear on the market unless they had been fully demonstrated as safe following rigorous scientific and technical assessment.

Advocates claim mandatory labels are needed so that some consumers can make a choice to avoid foods derived through biotechnology – and who could oppose informing consumers and enabling them to make an informed choice? The implication is that safety concerns justify special labels. But with no specific safety problem associated with biotech foods a "GMO label" provides the consumer with no information to make an informed choice about any risk to their health.

Instead, such a label would only tell the consumer about some aspects of the process by which the seeds were improved that led to the harvests which were ultimately used in the food. This information is almost never relevant to food safety, and where it is it must be disclosed as required by laws already in place. If such process-based labeling were required for organic food it should be labelled as having been fertilized with animal waste containing pathogens known to cause human disease, or to indicate when Bacillus thuringiensis (Bt) or carcinogenic rotenone were used on crops to control insects – processes common to most organic crop production?

Process-based labeling for biotech derived foods does not provide consumers with any information related to safety and can only lead to confusion and, in the case of biotech foods, unnecessary alarm and concern. Indeed, that is the frank objective of those pushing hardest for such labels.[54]

Consumers in most countries already can freely choose to avoid foods derived from crops improved through biotechnology, by seeking out the "organic" or "bio" label, knowing it prohibits organic farmers from planting biotech improved seeds. Those who choose such organic foods will, of course, pay the higher prices typical of such foods. But that is certainly fairer than a mandatory label which would force higher costs on all consumers, whether they want to pay the higher organic prices or not.

Since the facts show clearly that biotech foods are at least as safe, if not safer than alternatives (conventional or organic) it seems labeling advocates seek to use labels to mislead consumers by implying a safety concern that does not exist. For example, the ten-year study on biotech by the European Commission referenced above concluded:

> "The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research, and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not *per se* more risky than e.g. conventional plant breeding technologies."

Opponents of biotechnology often claim that untested biotech foods are free to be placed on the market even if there are concerns they may be unsafe, and that such foods are wrongly presumed by regulators to be "substantially equivalent" to conventional foods without any tests being done. Such claims are false.

Following years of work by the U.S. National Academy of Sciences and expert groups of the Organization for Economic Cooperation and Development (OECD), the principle of "substantial equivalence" was most fully described by the OECD in 1993. In this work the expert groups developed a long series of questions that should be, and today are routinely used to evaluate potential hazards from bioengineered foods.

After all these questions have been considered with respect to a particular food, if no differences relative to health, safety, or nutrition have been identified, only then is it concluded that the bioengineered food is substantially equivalent to other foods. In other words, this is a *conclusion* reached *after* extensive and painstaking analysis, not an *a priori* assumption. This approach has been endorsed by the United Nations World Health Organization and the Food and Agriculture Organization.

At the end of the day, the companies most opposed to mandatory GM labels on food are not the biotech companies – their products, which are seeds sold to farmers, all carry labels making clear they were produced through biotechnology. The companies most opposed to mandatory labels for "GM" foods are food companies, who are most directly threatened by the disinformation campaigns frequently launched by the professional biotech opponents for whom this issue has been such an effective fundraising tool.

The environment

Myth 8: Since biotech crops were introduced, pesticide use has increased.

Reality: Untrue. If this myth had any validity, why has the U.S. agrochemical industry experienced declining demand for farm chemicals at the same time that agricultural output is increasing?

The overall reduction in chemical use was one of the early and clear benefits to farmers who grow both insect resistant and herbicide tolerant crops. A June 2009 report by German researcher Dr. Matin Qaim concluded that: *"GM crops bring about environmental and health benefits. Bt crops in particular allow significant reductions in chemical pesticides."*[55] This has been amply reinforced by other studies in peer-reviewed literature, such as the report from Brookes & Barfoot (April 2013) which stated that:

"Biotech traits have contributed to a significant reduction in the environmental impact associated with insecticide and herbicide use on the areas devoted to biotech crops. Since 1996, the use of pesticides on the biotech crop area was reduced by 503 million kg of active ingredient (8.8% reduction), and the environmental impact associated with herbicide and insecticide use on these crops, as measured by the EIQ indicator, fell by 18.7%."[56]

Monsanto told investors to expect farm chemical sales to fall $1 billion, or 28%, by 2008 because biotech crops had reduced demand.[57] Bayer similarly blamed third quarter losses as far back as 2003 on worldwide weakness in its farm chemicals business and specifically on biotechnology-derived crops which had been increasing rapidly at the time and which required less chemical pesticides.[58]

Agribusiness consulting firm, Kline & Company, predicted corn, cotton and soybean farmers would spend $1 billion less on chemicals between 2004 and 2009 because of biotech varieties, while sales of conventional pesticides for corn will plummet, from $300 million in 2002 to just $70 million in 2012.[59] These predictions have been borne out by experience (Brooks & Barfoot, 2009).

In Canada, between 1995 and 2000 when the proportion of the canola (oilseed rape) crop that was biotech rose from 10% to 80%, the amount of herbicide used fell by 40%, equivalent to a 36% reduction in environmental impact (calculated by human and animal toxicity and environmental persistence).[60]

In Brazil, Aprosoja (the Federation of Soybean Producers) reported a 50% reduction in the use of agrochemicals despite producing a record crop in 2003.[61] According to the president of Brazil's Farsul Grains Commission, while producers of conventional soybeans use 2 litres of glyphosate, and another 5 or 6 litres of other herbicides per hectare, those growing transgenic soybeans needed **only** between 3 and 4 litres of glyphosate, which has the added advantage of being less persistent in the environment than the herbicides it displaces.

A 2008 report on adoption and performance of insect resistant corn in Spain by the European Commission's Joint Research Centre found that farmers who used Bt Corn used less to no chemicals compared to conventional corn growers.[62]

An earlier study of pesticides and conventional farming across Europe (Phipps and Park, 2002) calculated that if 50% of the corn, oil seed rape, sugar beet and cotton grown in the EU were existing biotech varieties, pesticide use per year would fall by 14.5 million kg of formulated product (4.4 m kg active ingredient) and the reduction in spraying would save 20.5 million litres of diesel and keep 73,000 tons of carbon dioxide from being released into the atmosphere.[63] All these indicators of declines in the use of pesticides, and of more toxic herbicides being superseded by newer weed control measures with lower environmental impacts, have been corroborated yet again by additional data from the Economic Research Service of the U.S. Department of Agriculture.[64] Arguments to the contrary have often relied on a selective use of data and invalid methodology, and cannot be taken seriously.[65]

Myth 9: Gene flow from biotech crops threatens biodiversity.

Reality: Out-crossing and herbicide resistance is a well-understood crop management problem that has occurred long before biotechnology was developed. There is no evidence that biotech crops are, or will be, any less manageable than their conventional counterparts.

Before the commercialization of biotechnology derived crops in the mid-1990s, herbicide tolerance in a weed had been documented 11,188 cases in 42 separate countries.[66] Some of these reflected the adaptation of weed populations to become tolerant, while others represent the inborn tolerance to one or another herbicide that most plants naturally carry.[67] To prevent such natural adaptation of weed populations to resist the herbicides applied, farmers need to alternate the use of *different* herbicides (possessing different chemical modes of action) from one season to the next, or even in the same season, where necessary.

By enabling the use of a herbicide that could not previously be applied to a given crop, biotechnology-derived herbicide-tolerant (HT) crops have increased the number of dissimilar herbicides in farmers' arsenals against weeds thereby *decreasing* the probability for herbicide-tolerant weeds to arise via the historical mode of selective pressure/adaptation.[68]

While studies corroborate a global 7% reduction in herbicide active ingredient applications, the improved environmental safety profile of the herbicides most commonly used in conjunction with biotech crops has resulted in a significant reduction – nearly 18% -- of the environmental footprint of biotech agriculture (Brooks & Barfoot, 2012).

There is no credible evidence that those biotech crops in development or commercial use are, or could become, more difficult to control, or that there would be any more troublesome weeds than arise with crop plants made herbicide tolerant by other means. The *New Scientist* reported in July 1999 that conventional sugarbeet in Europe had already out-crossed during the 1980s – i.e., *before* biotech crops had been developed - with a native weed to produce a resilient and troublesome "superweed". Systemic or other herbicides cannot be used as they would also kill the crop.

On the other hand, a 10 year study by a respected British ecologist found that biotechnology-derived herbicide-tolerant crops did not persist in the wild and were no more likely to invade other habitats than other, unimproved crop plants. The plants did not become self-seeding, self-sustaining plants, and they did not spread into surrounding areas.[69]

As a group of scientists at Britain's respected John Innes Centre concluded in a paper on the environmental impact of biotech crops (Dale, 2002), "we can find no compelling scientific arguments to demonstrate that biotech crops are innately different from non-biotech crops."[70]

Myth 10: Biotech corn threatens the Monarch butterfly.

Reality: Extensive scientific study has concluded that Bt crops have had no measurable effect on the Monarch. Indeed, it stands to benefit from reductions in pesticide spraying.

A single laboratory experiment showed that one kind of pollen from Bt corn could harm Monarch caterpillars if fed to them directly.

An extensive series of field experiments and observations have shown that Bt crops have had no measurable effect on the Monarch butterfly population and are not expected to do so in the future. As the UK's prestigious Royal Society pointed out in its October 2009 report *Reaping the Benefits* – "studies showed that *Bt* maize pollen did not in fact pose a threat as the density of pollen on the milkweed leaves on which monarch caterpillars feed is much lower than that which would cause harm".[71]

Because the Monarch butterfly winters in Mexican forests and migrates annually to the U.S., numbers are heavily affected by weather and habitat loss in Mexico. In 2000, 28 million Monarchs wintered in Mexico, but in 2001 nearly 100 million did.[72] More recently, severe drought along the southern migration is thought to have led to the lowest overwintering population on record. It is also likely that the population that started the southward journey itself was in fact reduced due to declines in the breeding habitat throughout the Midwestern US corn belt.[73] But measures are underway[74] to restore and improve the reproductive habitat for adult Monarchs, and it is hoped these will bear fruit.

The main impact from Bt crops, mainly Bt cotton, was to reduce the application of chemical insecticides by approximately one million litres per year in the southern United States. This undoubtedly helped preserve the lives of migrating Monarch butterflies.[75]
Since the Monarch episode, there have been claims that Bt cotton has harmed beneficial insects in China and other countries. In fact the reverse has been found. A 2003 study (Kongming Wu, 2003) discovered that the diversity of the arthropod community in Bt cotton fields was higher than in conventional cotton, as are bollworm insect predator levels, due to the much reduced use of insecticide.[76] In January 2010 scientists from five EU countries also concluded that Bt corn had little to no impact on butterflies and moths.[77]

Concerns about effects on bees have also been allayed. Trials[78] have found no effect on the health of bees which had been fed purified proteins of toxins expressed by Bt plants (designed to control caterpillars) or biotin-binding proteins (for general insect control), and only a slight effect with protease inhibitors (used for caterpillar and beetle control). Even then, these tests are extreme since flowering biotech plants produce only minute quantities of the new proteins in pollen which is what bees predominantly eat.

Further, claims that biotech crops have been responsible for so-called colony collapse in bee populations are not supported by any data. Indeed, colony collapse has occurred in many regions and countries where no biotech crops are grown such as California in the U.S. and the United Kingdom.[79] The best explanation seems to involve a series of factors, including pests (varroa mites), viral disease, and low levels of exposure to neonicotinoid seed treatments completely unrelated to biotechnology.[80]

Myth 11: The herbicides used on biotech crops damage the environment.

Reality: Biotech herbicide-tolerant crops not only reduce herbicide application, resulting in cleaner soil and water, they promote greater adoption of no-till farming which minimizes soil erosion and the release of climate-changing carbon into the atmosphere.

In general, the only herbicides that can be applied to biotech herbicide-tolerant crops are those that have fewer adverse environmental impacts than the "older" herbicide(s) they are replacing, which are being progressively prohibited both in Europe and the U.S. The new generation of herbicides has reduced longevity in the environment, lower toxicity to wildlife and/or humans, and either degrade into innocuous by-products (CO_2 and H_2O) so rapidly or adhere so tightly to soil particles that they do not leach into drinking water supplies.[81]

Far from harming the environment, herbicide tolerant crops have transformed much of U.S. agriculture by reducing the need to till (plow) the land. Thanks to no-till and other forms of 'conservation tillage', soil erosion and movement are minimized and soil health and water retention ability are maximized.[82] In addition, this helps in the reduction in CO_2 and other pollutants formerly emitted by plowing operations. No-till is also energy saving because just one operation - seed drilling - can be undertaken rather than conventional planting which needs three operations -- plowing, harrowing, and drilling.

Research published by G. Phillip Robertson, Eldor A. Paul, and Richard R. Harwood of Michigan State University has calculated that "no tillage" methods of crop production reduce modern agriculture's impact on global warming by approximately 88%.[83]

Modern agriculture accomplishes control of weeds either through mechanical cultivation or through the application of herbicides. Weed pressure will vary by location, but corn and soybean farmers who use only mechanical cultivation (e.g., "organic" farmers) need to cultivate their fields as often as fourteen times per growing season.[84]

By contrast, the "no tillage" and "minimum tillage" crop production methods use one and two to four cultivation applications respectively, which decrease soil erosion (wind & water) by 90% or more.[85]

When a farmer switches from intensive mechanical cultivation to "no tillage" or "low tillage" crop production, the population of earthworms subsequently increases in direct proportion to the amount by which mechanical cultivation is avoided.[86] A study of conservation tillage by the American Soybean Association (ASA) found that 75% of growers who planted biotech varieties reported that there was more crop residue on the soil surface using biotech varieties.[87] Year after year, and layer after layer, this old crop residue breaks down to form new humic matter which is incorporated into the soil. As one Iowa soybean farmer puts it: "for the first time in agriculture we are building top soil."[88]

The switch in crop production methods also helps remove carbon dioxide from the Earth's atmosphere, because avoidance of over-cultivation allows the natural fungi that grow on plant roots to produce glomalin, a protein that naturally sequesters carbon and keeps it within the soil. Glomalin helps to improve the fertility of soil by acting as a sort of "glue", causing soil particles to clump together properly. It creates subsurface spaces that allow water, oxygen, and plant roots to permeate the soil.

The presence of glomalin is one of the main differences (apart from water) between fertile cropland soil and lifeless desert sand. The more that 'healthy' cropland soil is disturbed by mechanical cultivation, the more that the glomalin is broken-up and its (formerly sequestered) carbon allowed to enter the atmosphere in the form of the "greenhouse gas" carbon dioxide.

Myth 12: Biotech crops are inherently risky to the environment.

Reality: There is no evidence to show that biotech crops are more "risky" than their conventional or organic equivalents.

As referenced above in the Brookes and Barfoot global impact on the environment of biotech crops report, biotech crops benefit the environment through reduced tillage, reduced diesel fuel use and reduced chemical use. Brookes and Barfoot report that in 2012, the combined biotech crop-related carbon dioxide emission savings from reduced fuel use and additional soil carbon sequestration were equal to the removal from the roads of 11.9 million cars, equivalent to 41% of all registered cars in the UK.[89]

In line with other reports a thorough review of this issue was carried out by New Zealand scientists Tony Conner and Travis Glare and their Dutch colleague Jan-Peter Nap.[90] After reviewing 250 published research papers which studied a wide range of environmental impacts, 'weediness', horizontal gene flow, ecological, biodiversity and other concerns about gene technology, they concluded that many of the problems which have come to be blamed on biotech crops do not exist, and those that do are equally applicable to conventional or organically grown plants.

Major conclusions[91] of the review were:

- Biotech crops were no more likely than traditional crops to lead to pest and disease problems;
- Biotech crops were no more likely to become weeds outside farming situations than other cultivars;
- Biotech crops were no more invasive, persistent or likely to become weeds than conventional counterparts;
- Biotech crops were no more likely to transfer transgenes, or any other gene, than other crop cultivars;
- Horizontal gene transfer could occur at exceptionally low frequencies, but there was no known mechanism through which this could create problems requiring management more often for biotech crops than others;
- Rigorous, peer-reviewed, scientific publications failed to identify undesirable effects on insect predators from biotech crops modified for insect resistance compared with traditional crops;
- The examples of secondary effects which have been discovered to date are minor (if real) and have not shown problems at an ecosystem level;
- The use of biotech crops has led to huge reductions in pesticides, with concomitant benefits to non-target insects and general agro-biodiversity. [92]

Myth 13: Biotech crops offer no environmental benefits.

Reality: Believing this proposition requires that one ignores: more insect and bird life because of reduced insecticide spraying, less pressure on wilderness because of more productive farmland, reduced carbon emissions, less soil loss from herbicide-driven conservation tillage and reduced impact of animal agriculture from low nitrogen/low phosphorous feed crops.

All but the last point have been addressed in detail elsewhere in this document. See also a June 2012 paper from Chinese scientists who concluded in a study spanning two decades that Bt cotton delivered significant environmental benefits including those non-biotech crops planted in neighboring fields.[93]

The impact of biotech crops on making animal farming less polluting is often ignored, yet by lowering the amount of excess protein and phosphorous fed to poultry and livestock, biotechnology can make a dramatic difference to the amount of pollution emitted by animal agriculture.
A paper published by The Council for Agricultural Science and Technology (CAST) calculates that new technologies such as low-phytate corn and soybeans could help decrease nitrogen and phosphorus excretion by swine and poultry by up to 40% and 60%, respectively. Improving bovine digestive systems could reduce N excretion by as much as 34% and phosphorus excretion by 50%.[94]

Further, a 2010 study showed that growers growing conventional corn next to Bt corn benefited from the reduction in European corn borer pressure. The study, covering 14 years of records in the top US corn-producing states of Minnesota, Illinois, Iowa, Nebraska and Wisconsin, showed that in neighboring fields non-Bt corn borer populations were lower by 28-78%, depending on how much Bt was grown in the surrounding area.

The study also calculated that the total economic benefit over the 14 years came to $6.8 billion. The study valued the extra corn harvested because of the reduction in corn borer numbers and took into account the extra $1.7 billion farmers had paid for the biotech seeds, equivalent to $10-20 per hectare. The reduction in pests due to Bt corn was significant in the fields where it was planted, but two-thirds of the total benefit in pest reduction was seen in neighboring fields where non-Bt corn was grown: in other words, the benefits of pest control by Bt corn were most strikingly seen in adjacent, non-Bt corn fields.[95]

Myth 14: Biotech crops are not necessary for no-till agriculture.

Reality: Although no-till has been attempted since chemical herbicides were first introduced, it was seldom easy or cost-effective until biotech varieties became available.

An analysis of surveys conducted since the introduction of herbicide tolerant (HT) crops (Fawcett, 2002) "strongly supported" the conclusion that biotech crops have facilitated a dramatic and unprecedented expansion of conservation tillage since 1996, thereby saving one billion tons of soil per year and providing a beneficial habitat for birds and mammals, reducing phosphorous and nitrogen run-off, and reduced atmospheric carbon dioxide through escaping soil carbon and tractor fuel used for plowing.[96]

It is important to appreciate that before the availability of herbicide-resistant soybeans, farmers had to use soil-applied herbicides, which were sprayed onto the field before planting, and whose efficacy was often reduced by the presence of prior-crop residues inherent in no-till production practices.

Other inherent no-till limitations prior to 1996 included:

(a) Narrow "time windows" during which a farmer could apply the (few) herbicides then available over the top of growing soybeans. Spraying too early could damage or kill the soybean plants; spraying too late risked a lack of weed control because the too-large weeds would not be killed by the herbicides that were used. Thus a week or two of rainy weather could have proven devastating to weed-control efforts in pre-1996 no-till soybeans.

(b) High risk for utilizing the emerging production practice known as narrow-row soybeans (i.e. closer planting more efficiently utilizes sunlight and conserves more topsoil moisture by shading the ground with leaf canopy). Since the farmer cannot fall back on mechanical tillage for weed control (as he cannot drive between the rows), his agrochemical weed control must be reliable for narrow-row soybeans to work.

In the words of Mississippi University Agricultural and Forestry Experiment Station researcher Dr. Norman Buehring, "Narrow-row soybeans can bring with them yield increases, but not without (reliably) winning the war against the weed known as sicklepod, which can also reduce yields by as much as 35% (if not controlled).[97]

Agricultural practice

Myth 15: Biotechnology has been a bad deal for farmers.

Reality: Biotech has transformed global agriculture, making commodity crops cheaper and easier to grow while reducing chemical inputs.

For a technology that some claimed would be an economic disaster, farmers across the world have been conspicuously enthusiastic about agricultural biotechnology – when they have the opportunity to use it on their farms. Seventeen years ago biotechnology-derived, herbicide tolerant soybeans did not exist commercially, yet in 2012, they were planted on more than 94% of U.S. soybean acres, 76% of U.S. cotton acres and 75% of U.S. corn acres (USDA).[98]

In Brazil, which began legally cultivating herbicide tolerant soybeans in 2003, 85% of the soybean crop was biotech by 2012;[99] and in Argentina the crop was more than 95%. Elsewhere, moreover, every year since 1996, the acreage sown to biotech crops has increased substantially to the extent that by 2011, nearly 17 million farmers (most of them in developing countries) across 29 countries planted 160 million hectares (395 million acres). In 1996, the first year of biotech crops, the total production area was 1.7 million hectares (4.2 million acres)

The rapid growth of agricultural biotechnology cannot be attributed to farmers' blind enthusiasm. Biotech crops have saved them money and reduced their workload. As well as being stewards of the land and living in the environment that others worry about, farmers are businessmen. If a tool or a technology did not work they simply would not use it. If biotechnology did not deliver, if it did not offer farmers benefits in terms of operational efficiency, land husbandry and profitability, they simply would not use it year after year. Brookes and Barfoot point out in their 2014 study, that:

> ".....GM technology has had a significant positive impact on farm income derived from a combination of enhanced productivity and efficiency gains. In 2012, the direct global farm income benefit from biotech crops was $18.8 billion. This is equivalent to having added 5.6% to the value of global production of the four main crops of soybeans, maize, canola and cotton. Since 1996, farm incomes have increased by $116.6 billion.

The largest gains in farm income in 2012 have arisen in the maize sector, largely from yield gains. The $6.7 billion additional income generated by GM insect resistant (GM IR) maize in 2012 has been equivalent to adding 6.6% to the value of the crop in the GM crop growing countries, or adding the equivalent of 3% to the $226 billion value of the global maize crop in 2012. Cumulatively since 1996, GM IR technology has added $32.3 billion to the income of global maize farmers.

Substantial gains have also arisen in the cotton sector through a combination of higher yields and lower costs. In 2012, cotton farm income levels in the GM adopting countries increased by $5.5 billion and since 1996, the sector has benefited from an additional $37.7 billion. The 2012 income gains are equivalent to adding 13.5% to the value of the cotton crop in these countries, or 11.5% to the $47 billion value of total global cotton production. This is a substantial increase in value added terms for two new cotton seed technologies.

In Brazil, a 2012 report by an agricultural economist consultancy, Celeres, reported that:

> "…..over the last fifteen years … out of the $11.9 billion resulting from the benefits, 44% of the benefits was an outcome of gains in productivity, in comparison to 27% in the previous year, mainly boosted by GM corn. Last year, the major benefit-generating factor was cost reduction, which translated into 52% of the benefits throughout the period at stake. Currently, this segment responds to 37% of the total."[100]

In Europe, farmers increasingly want to have the choice to grow biotech crops. Currently, only an insect resistant biotech corn event – approved in 1996 – is available. Spanish farmers have been enthusiastic users of this corn and production accounts for 85% of the 116,000 hectares (286,636 acres) of the production grown in only six EU countries.

However, no other commercial biotech crop varieties have been approved in the EU since 1996 given the highly charged political, regulatory and media climate. A 2011 study on EU farmers' attitudes toward biotechnology showed that "economic issues such as the guarantee of a higher income or the reduction in weed control costs were found to be the most encouraging reasons for both potential adopters and potential rejecters of adopting [herbicide tolerant] crops.

The study found that:

> "……Over half of German farmers and almost half of Czech and UK farmers would be keen on adopting GMHT OSR (genetically modified herbicide tolerant oilseed rape) whereas over a third of Spanish, French and Hungarian farmers would be keen on adopting GMHT maize. The fact that GMHT OSR is relatively more appealing to EU farmers than GMHT maize is probably reflecting a relatively higher complexity of treating weeds in the case of OSR crops than maize crops.[101]

A 2012 report showed that about one-third of Swiss farmers interviewed would grow biotech crops if they offered solutions for production problems such as disease resistance. Farmers also believed that biotech crops would help cut production costs in Switzerland, especially if no-till practices were introduced and they believed that herbicide tolerant oilseed rape, maize or sugar beet would help to increase net margins.[102]

Political stonewalling and ideologically motivated opposition have resulted in European farmers losing access to a technology rapidly adopted by their counterparts in other countries. The failure of political will to counter activists' propaganda and consumer misunderstanding has denied European farmers full access to the technology.

For example, the Secretary-General of the EU farmers' and farm cooperatives association, Copa-Cogeca, while mindful of consumer concerns, nevertheless called for EU farmers to have access to biotech crops:

> "…..Farmers in Europe should have the right to be able to choose and to use this technology. But it is also important for farmers to have consumer acceptance and consumers in Europe have so far been reluctant to buy genetically modified produce…….The EU regulatory framework for approving genetically modified organisms needs to be correctly implemented.
>
> Farmers are often hesitant to grow these crops due to the additional administrative burden, consumer resistance and fears that their crops may be destroyed. In the future, we want to ensure that we have a sustainable, productive and profitable EU agriculture sector to provide high quality food for 500 million consumers and to meet growing world food demand. The use of modern biotechnology can help us to achieve this, but it must be based on sound scientific advice, an efficient EU regulatory procedure and it must have consumer acceptance".[103]

In South America the technology has been rapidly adopted and in Argentina, Brazil, Paraguay, and Uruguay more than 40 million hectares of biotech soybeans were planted in 2011, according to a report by the Argentine Ministry of Agriculture, Livestock and Fisheries and the Inter-American Institute for Cooperation on Agriculture published in October 2012. The report concluded that:

"…..In order to obtain current yields, the growing of conventional soybeans requires a larger surface area and ground labor than the growing of GM soybeans. Furthermore, it is more polluting to the water, air, and soil owing to the use of various agricultural chemicals, and contributes more to greenhouse gas emissions. The introduction of GM soybean seeds has revolutionized the crop in the four countries, because of the ease of agronomical management, weed control, and the reduction of production costs".

The report went on to point out that the economic difference between the direct costs of cultivation of biotech and conventional seeds is 15% in favor of the technology detailed in the report.[104]

Myth 16: Farmers are at the mercy of biotech chemical companies for their seeds and chemicals.

Reality: The large and vigorous industry of traditional seed suppliers – more than 550 in America alone - underlines the fact that non-biotech seeds remain freely available and widely used.

The success of herbicide tolerant soybean production has resulted in much greater availability of many soybean varieties across all climatic zones in the U.S. However, non-biotech soybean varieties remain available for organic growers and those who wish to grow non-biotech soybeans. There are also around 100 independent seed companies (not owned by biotech firms) currently marketing soybean seed with which those seed firms acquired by biotech companies have to compete.

Traditionally farmers used a number of chemicals to control weeds. Some chemical worked better than others. Some chemicals which were over-used resulted in weed resistance, such as sulfonated urea and imidazole, triazine herbicides, or paraquat[105]
There are a number of different modes of action in herbicides that have been used in the past 50 years. It usually takes about a decade of use before significant tolerance evolves in targeted weed populations (with glyphosate, it has taken about a decade and a half for glyphosate tolerant weeds to become a problem in some areas). It should be noted that all of them have been labeled and marketed for use against some weeds but not others, due to the inborn tolerance for some (different) herbicides that nearly all plants have.
When tolerance emerges as a problem after a decade or more of use, this is usually due to one or another (sometimes both) of two phenomena:

(i) the emergence of a weed that didn't used to be a problem, to fill an ecological niche left vacant by the effective control/eradication of the once major but now dethroned king weed (this is what seems to be happening with glyphosate resistant weeds);
(ii) the evolution of *de novo* tolerance in the targeted weed population, wherein the herbicide that initially provided good control now loses its effectiveness.

Both the above cases are exacerbated by farmers who fail to follow the good agronomic practice of rotating modes of action among weed control treatments.

When farmers grow herbicide tolerant crops, they are able to reduce their overall chemical use even if they use more of those chemicals to which their crops are tolerant (see Brookes and Barfoot 2014). However, sound management practices are necessary to avoid overuse resulting in weed resistance.

There are cases of emergence of weed resistance to glyphosate as reported by the U.S. National Academy of Sciences (April 2010).[106] However, weed resistance to chemicals is not new[107] and is not a result of biotechnology as such. In many cases, it is a result of poor management practices where some farmers rely too much on any single herbicide (e. g. glyphosate) and have not employed usual practices of crop rotation and varying tank mixes of herbicides as reported by Brookes and Barfoot in their 2012 report on the global environmental impact of biotech crops:

> "It should, however, be noted that in some regions where GM HT crops have been widely grown, some farmers have relied too much on the use of single herbicides like glyphosate to manage weeds in GM HT crops and this has contributed to the development of weed resistance. There are currently 25 weeds recognised as exhibiting resistance to glyphosate worldwide, of which several are not associated with glyphosate tolerant crops (www.weedscience.org). For example, there are currently 14 weeds recognised in the US as exhibiting resistance to glyphosate, of which two are not associated with glyphosate tolerant crops. In the US, the affected area is currently within a range of 15%-40% of the total area annually devoted to maize, cotton, canola, soybeans and sugar beet (the crops in which GM HT technology is used).

> In recent years, there has also been a growing consensus among weed scientists of a need for changes in the weed management programmes in GM HT crops, because of the evolution of these weeds towards populations that are resistant to glyphosate. Growers of GM HT crops are increasingly being advised to be more proactive and include other herbicides (with different and complementary modes of action) in combination with glyphosate in their integrated weed management systems, even where instances of weed resistance to glyphosate have not been found. This proactive, diversified approach to weed management is the principal strategy for avoiding the emergence of herbicide resistant weeds in GM HT crops. It is also the main way of tackling weed resistance in conventional crops. A proactive weed management programme also generally requires less herbicide, has a better environmental profile and is more economical than a reactive weed management programme"[108]

Weed resistance where it occurs can be managed by the familiar methods of crop rotation, alternation of different herbicide modes of action and management of the weed seedbank. The incorporation of pre-emergent residual herbicides into the herbicide program is particularly effective. In especially difficult cases it may be necessary to implement a combination of chemical, cultural and mechanical control measures to effectively manage resistant weeds. This is no different for glyphosate-resistant weed populations than it has been for dealing with weed populations resistant to triazine, ALS, or PPO herbicides.

Also see U.S. National Research Council proceedings of a weed resistance summit published in October 2012.[109]

Myth 17: Biotech crops only suit U.S. agriculture.

Reality: Biotech crops are widely grown outside the U.S. One-third of the world's biotech crop acreage lies in developing countries where the take-up of agricultural biotechnology continues to advance twice as fast as in industrial countries.

The ISAAA (International Service for the Acquisition of Agribiotech Applications) reported in its annual report (February 2014) that in 2013, biotech crops were grown legally in 27 countries. Ninety percent of the 18 million farmers growing biotech crops are smallholders in the developing world (see www.isaaa.org).

Brooks and Barfoot (2014) report that:

> "In relation to the nature and size of biotech crop adopters, there is clear evidence that size of farm has not been a factor affecting use of the technology. Both large and small farmers have adopted biotech crops. Size of operation has not been a barrier to adoption."

Countries which are major producers of biotech crops include Canada, Argentina, Brazil, China and South Africa. More than 30 percent of Spain's corn is biotech with production in 2013 increasing by 20,655 hectares on 2102, and Australia and India are important growers of biotech cotton. Burkina Faso, Bolivia, and Egypt also now grow biotech crops on a commercial scale, joining Mexico, Honduras, Colombia, Chile, Uruguay, Paraguay, the Czech Republic, Portugal, the Philippines, Romania and Slovakia.[110]

A detailed study of Argentinian grain production (Trigo and Cap, 2004) concluded that biotech crops 'played a strategic role in the growth of the [agricultural] sector - not only because of their direct impact, but also due to their interaction with other technologies and their global macroeconomic effect through their impact on the country's agricultural exports.[111] In China, the introduction of Bt cotton has saved not only farmers' money but also lives by the hundreds, by reducing the risk of misuse of poisonous pesticides.[112]

India has become the second largest cotton growing country in the world largely due to a spectacular adoption rate of biotech cotton production. In 2002, Bt cotton was introduced and grown on 123,500 acres. By 2012, more than 7.2 million farmers (up from 6.3 million in 2010) were growing Bt cotton on more than 10.8 million hectares – some 93% of total cotton production.[113]

Myth 18: Biotech crops have been banned in the European Union.

Reality: Demonstrably false. The EU both imports and grows biotech crops. It has legislation in place for import and processing and cultivation of biotech crops and foods.

The EU has experienced probably more anti-biotech concerns among consumers and politicians than any other region, clearly a consequence of a well-funded and very active professional opposition. The intensity of the issue and the fact that some member states attempted to ban cultivation of the EU-approved Bt corn without any scientific or legislative justification prompted the myth that the EU has banned all biotech crops and food. However, the reality is that: the EU has legislation in place governing the import, development and commercialization of biotech crops and food; the EU imports more than 30 million metric tons of biotech soybeans from the U.S. and South America – every year.

The national governments who try to implement bans must demonstrate that there is scientific evidence to justify claims that the biotech corn could cause 'damage' within the national borders. To date, none of the countries who have instigated these 'illegal' bans in violation of European law (the corn in question is fully authorized for cultivation in the EU) has provided data acceptable to the European Commission. Indeed, the European Food Safety Authority in June 2009 reaffirmed the safety of the insect resistant corn.[114]

These politically inspired national bans have been condemned by numerous scientists and farmers in the EU not only because they go against a legally approved biotech crop but also because they undermine both science and consumer acceptance of biotechnology.[115]

The continuing political rejection by some EU Member States has slowed the EU's biotech approval process. This is of considerable concern to animal feed companies and farmers and poultry producers because slow approvals mean that biotech crops approved and commercialized in other countries and not approved in the EU will be barred entry. For example, a biotech trait that has been thoroughly assessed in the U.S. can expect to receive market authorization in 15 to 18 months. In Brazil, approval timelines are even less - 12 to 16 months. The EU average authorization timeline is approximately four years.

Myth 19: Biotechnology has failed to increase yields.

Reality: Biotech crops do increase yields by reducing the amount lost as a result of insect damage and weed proliferation. They also reduce costs per acre/crop weight, therefore increasing economic yield.

This myth has been most creatively promoted in a paper self-published by a professional protest group[116]. The paper has been debunked not only by critical reviews[117] but also by concrete experience. Herbicide-tolerant crops allow farmers to better control weeds which would otherwise compete with the crop plants and prevent them growing properly.

Insect-resistant plants protect the crop from attack, especially from insects such as corn borer and bollworm which are notoriously difficult to control with sprays. In both cases, biotech crops provide a means to control yield threats with less cost, less effort (e.g. fewer sprayings) and less chemical use.

Herbicides have proved essential in maintaining yields without driving up costs prohibitively. A National Centre for Food & Agricultural Policy (NCFAP) study (Gianessi, 2003) calculated that without herbicides, crop producers could employ six million more workers to pull up weeds and still lose 20% of their crop to competition from weeds.[118]

In 2009, U.S. soybean growers had access to a higher yielding glyphosate tolerant soybean. The technology offered the same tolerance to glyphosate as the first generation (and the same cost saving) but with higher yielding potential. Results for that year's crop were mixed mainly because this 'second generations' of soybeans was only available in limited quantities and not available in many of the leading (best performing) seed varieties.

However in 2010 and 2011, when the trait was available in many more of the leading varieties, farmers reported higher average yields. For 2010, Brookes and Barfoot applied an average yield improvement of +5% average yield and calculated that by applying the same cost saving assumptions as applied to first generation soybeans, but with a seed premium of $65.21/ha ($161 an acre) for 2009 and $50.14/ha ($124 an acre) for 2010, the net impact on farm income in 2010, inclusive of yield gain, was +$72.87/ha ($180 an acre).

Aggregated to the national level this was equal to an improvement in farm income of $176.87 million in 2010 and over the two years the total farm income gain was $202.3 million. The technology also increased US soybean production by 446,000 metric tons over the two years (Brookes and Barfoot 2012).

Myth 20: Biotechnology offers at best only minor benefits.

Reality: The transformation of the economics of soybean, cotton and corn production, with reduced costs, increased farmers' profits and lower chemical use, are hardly minor gains. In the case of the U.S. grown papaya, biotechnology has saved an entire industry.

Biotechnology saved Hawaii's papaya industry from economic disaster. In 1992, ringspot virus (PRSV) was discovered in the key papaya growing area of Puna on Hawaii Island. Within three years the industry was in crisis. Scientists at Cornell University developed two transgenic varieties, Rainbow and SunUp, which were resistant to PRSV and could be planted without farmers first having to clear their land of infected trees.

Today, biotech varieties have so reduced the PRSV 'viral load' in Hawaii that production is back to 1992 levels and even non-resistant varieties, including organic ones, can be grown with confidence. Importantly, on December 1, 2011, Rainbow Papaya from Hawaii was fully approved for commercial shipments to Japan marking the end of a long approval process which started in 1999. This is the first horticultural product, and the first direct-to-consumer food product to gain regulatory approval in Japan.[119]

Myth 21: Farmers lose out because they cannot save biotech seeds.

Reality: The cost of seed is a relatively small part of a modern farmer's total cost of production, and the benefits of getting the latest varieties, selected to suit weather and soil conditions or expected pest pressures, and guaranteed by the breeder, invariably outweigh the savings and hassle of retaining enough seed from the previous harvest. All these considerations existed long before biotechnology came along.

There is no requirement for farmers to buy seed. They do so because it makes production sense. For modern open-pollinated field crops to which hybridization imparts a significant yield advantage (as a result of "hybrid vigor"), saving seeds is actually a disadvantage for most commercial farmers who enjoy higher profits from increased yields due to buying new seed each year.

Seed companies are better able to prevent plant-disease-transmission via seed and are better able to preserve quality via scale economies in storage infrastructure. Seed companies also continually improve seed genetics to increase yield and disease resistance. These benefits are missed by farmers who save their own seed, although it is recognized that some impoverished farmers in developing countries have little choice.

Every commercial farmer knows that the most important factor is not the cost of the seed but the net value of the resulting crop. In the U.S., less than 5% of soybean is grown from previously saved seed even though, being a self-pollinated crop, farmers can easily and legally save non-patented/non-PVP seed varieties.

A closely related myth is the claim that the biotech seeds cannot be saved because they are sterile, and their sterility will disable the ability of farmers to save other seeds that hybridize with biotech seeds containing this “terminator” technology[120]. The deficiencies of this conspiracy theory are several: sterile seeds cannot convey any traits to subsequent generations because they are, by definition, incapable of reproduction.

Additionally, the so called “terminator” technology consists of a patent which was, jointly developed by a cotton seed company and the Agricultural Research Service of USDA[121] but has never been implemented in practice. In other words, no such “terminator” seeds are on the market, and none has ever actually been created.

Finally, the myth ignores the fact that the likely result of such “genetic use restriction technologies” would be to encourage private investment in seed improvement for open pollinated crops that have so far not enjoyed such productive attention. There are a number of technically more promising solutions to this problem that are under development[122], though none is, as yet, even close to market.

Myth 22: Farmers are often sued by seed firms.

Reality: Only a handful of farmers have breached their license agreements which they voluntarily signed. Moreover, it is very easy for biotech firms and farmers alike to differentiate between accidental contamination and deliberately grown seed.

Fifty eight countries have acceded to the International Union for the Protection of New Varieties of Plants (UPOV).[123] UPOV, established in 1961, comprises countries that have jointly agreed to mutually protect the intellectual property of people/companies who are willing to invest the effort and resources to develop novel plant varieties (thereby benefiting mankind through greater agricultural productivity).

Patents are among the methods used by seed companies to protect the intellectual property inherent in their proprietary crop varieties. Patents can be used to protect novel varieties that were developed through either biotechnology or traditional plant breeding methods. A farmer purchasing the seed of a patented variety signs a license to that patent, agreeing to only plant it for one season.

Some farmers have claimed that their “traditional-variety seed” became contaminated with biotech varieties through cross-pollination, only to be subsequently sued by the biotech-patent-holding seed company. Such cross-pollination would be irrelevant for self-pollinated crops such as the soybean, but even for open-pollinated crops, any such cross-pollination would be very small at best.

The most prominent of the farmers who have claimed to be “innocent” victims of traditional-variety seed “contaminated” through cross-pollination, Percy Schmeiser of Canada, was found by the court to have seed bearing the patented biotech trait at nearly 100 percent levels in his crop. Further, it was uniformly “contaminated” across his fields, which is the opposite of what would be the result of cross-pollination. Unsurprisingly, this farmer comprehensively lost the original case, his first appeal and his subsequent appeal to the Supreme Court of Canada.[124] [125] [126]

Myth 23: Biotech has nothing to offer developing countries.

Reality: All developing countries already benefit from biotechnology through cheaper commodity imports, lower mycotoxin levels, and higher and cleaner crop yields in domestic planting. Countries that grow biotech crops also benefit from reduced chemical use, higher yields and a more competitive agriculture.

Crops improved through biotechnology were grown legally in 27 countries in 2013, 19 of them developing countries. Ninety percent or more than 16 million of the 18 million farmers growing biotech crops are smallholders in the developing world (James, 2014). Developing countries, which tend to be major soybean importers, have benefited from the lower prices that accompanied most years' record soybean production. These lower prices have tended to occur frequently since a significant amount of biotech herbicide-resistant soybean seed became commercially available. The reduction in cost of inputs enabled soybean producers in major exporting nations to expand soybean acreage and increase production even while receiving a lower price per ton for their harvested soybean crop.
Corn-importing countries that procure their corn from countries where Bt corn is planted (e.g. U.S., Argentina, and Canada) have benefited since 1996 from the significant reduction in mycotoxin content of Bt corn varieties. Bt corn greatly reduces field formation of aflatoxin and other mycotoxins (formerly) produced in corn plants by fungi under certain environmental conditions[127].

Additionally, several developing countries depend on their own export of agricultural products for income and jobs. Argentina, for example, exports most of its (almost 100% biotech) soybeans. Its former Secretary of Agriculture Marcelo Regúnaga said in July 2002 that Argentine soybean producers saved about U.S. $400 million in crop production costs by cultivating biotech soybeans that year, and Bt corn farmers realized savings of up to 15 percent.[128]

Contrary to the claims of critics, small-scale farmers in developing countries are proving to be major beneficiaries of biotech crops, because 'in-seed' pest and disease protection saves on expensive and often hazardous chemicals, as well as reducing the effort of cultivation. Studies have shown that insect tolerant crops such as Bt cotton are scale neutral and suitable for small as well as large farmers. Evidence from India and other developing countries shows that the use of biotech crops helps to contribute to higher household incomes and poverty reduction, when embedded in a conducive institutional environment.[129]

A wide-ranging paper by Britain's independent Nuffield Council on Bioethics[130] concluded that, on a case-by-case basis, biotechnology had not only benefitted small farmers, but had the potential to do much more if crops such as bananas modified to resist serious fungal diseases, and plants that are drought and salt-tolerant were available to farmers.

Note: Anybody who wishes to know more about the potential for biotechnology in developing countries should consult 'Genes For Africa: Genetically Modified Crops In The Developing World' by Jennifer A. Thomson University of Cape Town Press (2002). Professor Thomson is a professor of microbiology at Cape Town University, South Africa.

Myth 24: Organic farming offers a better future than biotechnology.

Reality: Biotech crops are crucial if the food needs of the world's growing population are to be met reliably and without unacceptable encroachment on bio-diverse habitats.

Most U.S. farm organizations have farmer members who use organic, conventional, and biotech methods. Studies and experience show conclusively that far from being incompatible, they are, scientifically, potentially highly compatible and complementary[131]. Organic farming has its place and its strengths are concentrated in the low-yield production of food for those consumers willing to pay substantial premiums for a more labor-intensive product they perceive as "natural" even though studies do not find any consistent safety or health benefits.[132]

For price-sensitive commodity crops such as wheat and cotton, and soybeans and corn for animal feed, all of which comprise a major part of U.S. farming, organic methods are too costly, too variable in yield, and too prone to insect and weather problems to work on a mass scale.

Several (sometimes contradictory) comparative studies of organic and conventional farming methods have been produced recently, but all admit to a significantly reduced yield (when measured over several years without excluding fallow or "difficult weather" periods) as well as increased labor input for the organic systems.

The experience of Mr. Lynn Jensen of South Dakota is probably typical when he reported to *Soybean Digest* that not only do his organic soybeans require three to four times the amount of tillage as biotech varieties, but that they result in a 30% to 40% yield drag.[133] For this and many other reasons, modern no-till farming using biotechnology such as herbicide-tolerant crops approaches the epitome of low impact, sustainable, and affordable agriculture.

A report by the Council for Agricultural Science and Technology (CAST) carried an extensive literature review which compared biotech, conventional and organic soybean production systems in terms of sustainability. The report concluded that all three systems were environmentally sustainable and could be managed for profit. However, it pointed out that a high premium was needed for organic soybeans to compensate for lower yields and ensure the crop could be produced profitably.[134]

Scientific and medical resources

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British Medical Association

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UK Government GM Science Review Panel

Reports commissioned by the British government from its committee of experts during 2003 and 2004.
http://www.gmsciencedebate.org.uk/report/default.htm

Council for Agricultural Science and Technology

Numerous publications on the experiences of farmers dealing with agricultural biotechnology in crop and livestock production. http://www.cast-science.org/publications.asp

International Service for the Acquisition of Ag Biotech Applications

Reports documenting the global spread of agricultural biotechnology applications. http://www.isaaa.org/.

PG Economics

Numerous reports documenting the economic and environmental impacts of agricultural biotechnology crops around the world. http://www.pgeconomics.co.uk/

Science archives and background material

International Centre for Genetic Engineering and Biotechnology (ICGEB)

Comprehensive bibliographic database on biosafety. Over 4,700 science and policy documents.
http://www.icgeb.org/~bsafesrv/

ILSI International Food Biotechnology Committee

International documents and scientific publications on plant biotechnology and the safety assessment of food products derived from plant biotechnology (September 2004).
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U.S. Regulatory Agencies Unified Biotechnology Website

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AgBioForum (Journal of Agrobiotechnology, Management, & Economics)

AgBioForum is a free online service which publishes short, non-technical articles on current research in agricultural biotechnology. It is financed by the Illinois Missouri Biotechnology Alliance (IMBA) which is supported by a Congressional Special Grant to provide funding for University biotechnology research. AgBioForum is edited at the University of Missouri-Columbia with the assistance of advising editors from all areas of its intended audience, including academia, private sector, government, and agribusiness media.
http://www.agbioforum.org

Academics Review

A website created by independent academics that applies standards of scientific peer review to safety claims about crops and foods, particularly biotechnology, that are widely circulated in the popular media.
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