



Scientific Facts on Genetically Modified Crops

Source document:
FAO (2004)

Summary & Details:
GreenFacts

Level 2 - Details on Genetically Modified Crops

1.	What is agricultural biotechnology?.....	3
	1.1 How is agricultural biotechnology defined?.....	3
	1.2 How have agricultural technologies evolved over time?.....	3
2.	How can biotechnology be applied to agriculture?.....	4
	2.1 What are genes?.....	4
	2.2 What can be learnt from studying the genetic makeup of a species?	4
	2.3 What are molecular markers and how are they used?	5
	2.4 How can laboratory techniques help in growing and selecting plants?.....	5
	2.5 How can genetic engineering transfer characteristics from one species to another?.....	6
	2.6 What characteristics can be transferred to plants?.....	7
3.	Does conventional plant breeding have effects on health and the environment?.....	7
4.	Are genetically modified plant foods safe to eat?.....	8
	4.1 Could genetically modified plant foods have health effects?.....	8
	4.2 How should genetically modified food safety be assessed?.....	8
	4.3 How should genetically modified foods be labelled in the market place?.....	9
5.	What effects could genetically modified crops have on the environment?.....	9
	5.1 What direct effects could genetically modified plants have on the environment?.....	9
	5.2 What indirect effects could genetically modified plants have on the environment?.....	11
	5.3 How should these environmental effects be assessed?.....	12
6.	What are the implications of GM-technologies for animals?.....	12
	6.1 What are possible effects of genetically modified animal feed?.....	12
	6.2 What are possible effects of genetically modified animals?.....	13
7.	Are GMOs regulated by international agreements?.....	13
	7.1 How is international agricultural trade regulated?.....	13
	7.2 Do international conventions address environmental effects of GMOs?.....	14
8.	Conclusions.....	14
	8.1 Conclusions on agricultural biotechnology.....	14
	8.2 Conclusions on environment and health effects.....	15

This Digest is a faithful summary of the leading scientific consensus report produced in 2004 by the Food & Agriculture Organization (FAO):
"The State of Food and Agriculture 2003-2004"

The full Digest is available at: <https://www.greenfacts.org/en/gmo/>



This PDF Document is the Level 2 of a GreenFacts Digest. GreenFacts Digests are published in several languages as questions and answers, in a copyrighted user-friendly Three-Level Structure of increasing detail:

- Each question is answered in Level 1 with a short summary.
- These answers are developed in more detail in Level 2.
- Level 3 consists of the Source document, the internationally recognised scientific consensus report which is faithfully summarised in Level 2 and further in Level 1.

All GreenFacts Digests are available at: <http://www.greenfacts.org/>

1. What is agricultural biotechnology?

1.1 How is agricultural biotechnology defined?

Biotechnology can be described as any technology that uses living organisms to make or modify a product for a practical purpose. Some traditional techniques have been used for thousands of years. Natural yeasts, for instance, have been used to make bread, beer, and wine through a process called fermentation.



The use of yeast to make bread is an example of traditional biotechnology
Source: GreenFacts

In the last century, more sophisticated techniques have used other micro-organisms to make antibiotics, amino acids, vitamins, and other useful products. Modern biotechnology, developed during the past 30 years, usually makes changes to the hereditary material of a living organism by a technique called genetic engineering or genetic modification.

Modern biotechnology is currently used industrially to make useful products such as vaccines, antibiotics, enzymes, and hormones such as insulin.

In crop plant breeding, biotechnologies are used to develop plants resistant to pests, diseases, drought, heat, or cold, as well as to improve the nutritional content of plant food.

Table 1: An agricultural technology timeline [see Annex 1, p. 16]

1.2 How have agricultural technologies evolved over time?

1.2.1 For about 10 000 years, humans have attempted to improve plant characteristics by selecting and breeding individuals with desired characteristics. As a consequence, modern plants now differ substantially from their ancestors.

Classical breeding involves the cross breeding of two individuals of the same or of two very closely related species. Each parent donates half of its genetic material (DNA) to its offspring, so non-beneficial characteristics may be introduced along with beneficial ones. This conventional method is thus slow and demanding since many generations may be necessary to retain the good characteristics and to eliminate the bad ones. Conventional or modern biotechnologies can be used to make the process more efficient. More...

1.2.2 Desirable and detrimental characteristics are determined by the genes carried by the parent plants and may differ as a result of natural variation in genes. Plant breeders have succeeded in increasing this genetic variation by treating plants with mutagens that cause changes in the genetic material of the plant. The individual plants obtained by this method can have genetic characteristics that may be difficult to find in nature.

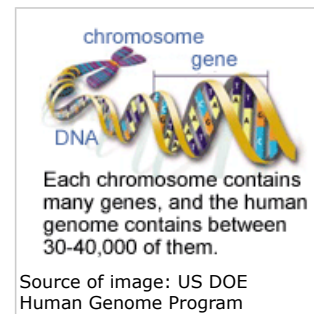
2. How can biotechnology be applied to agriculture?

2.1 What are genes?

The code which regulates all biological processes is stored in the DNA present in every cell of living organisms.

Only a small share of the DNA in a cell actually makes up genes, which contain coded information. The cells use this information to produce proteins, the basic building blocks and tools for running biological processes.

The role of the remaining share of the DNA is not yet clearly understood. The DNA in cells is generally organized into pairs of corresponding chromosomes with one set of chromosomes being inherited from each parent. An organism's entire set of chromosomes, and thus its entire set of genetic information, is called the genome.



The Human Genome Sequencing Project has decoded the genetic information contained in human cells. The project has developed many technologies and methods that can be applied to all living organisms. Other large genome-sequencing projects rely on international collaboration to study certain plants such as rice, which are considered representative of their biological group.

2.2 What can be learnt from studying the genetic makeup of a species?

2.2.1 The most significant breakthroughs in agricultural biotechnology are coming from research into the genetic mechanisms behind economically important characteristics and from genomics.

Genomics is the study of the complete structure of the genome. It provides information on gene structures and thus a basis for understanding protein structures. As a result, a theoretical model of an organism's biology may be built from a listing of its genes.

Comparing the relative location of genes on the chromosomes and DNA sequences in different organisms will significantly reduce the time needed to identify and select potentially useful genes. For most types of crops, livestock, and diseases, certain species have been studied as model species because they can be used to understand related organisms. Knowledge of the genome of model species is accumulating rapidly.

2.2.2 Different plant species tend to have a genome structure with very similar gene content and gene order along the chromosomes. This similarity is called "synteny". This means that the location of a gene which defines particular characteristics can easily be determined by comparing one genome to another. Therefore, it is not critical for our understanding to undertake the complete sequencing of plant genomes for all of crop plants with the great costs that this would entail.

As a consequence of synteny the knowledge of the biochemistry, physiology, and genes of a specific crop can now be transferred to other crops. This is particularly important in the case of so-called "orphan crops"; that are used in subsistence agriculture in many parts of the world. These crops have not attracted the research money that wheat, rice, and maize have received over the past century.

2.3 What are molecular markers and how are they used?

2.3.1 Molecular markers are specific fragments of DNA that can be identified within the whole genome. The markers are found at specific locations of the genome. They are used to 'flag' the position of a particular gene or the inheritance of a particular characteristic. In a genetic cross, the characteristics of interest will usually stay linked with the molecular markers. Thus, individuals can be selected in which the molecular marker is present, since the marker indicates the presence of the desired characteristic.

2.3.2 Molecular markers can be used to select individual plants or animals carrying genes that affect economically important traits such as fruit yield, wood quality, disease resistance, milk and meat production, or body fat. Measuring such characteristics by conventional methods is much more difficult, time-consuming, or expensive, since it requires the organism to grow to maturity.

2.3.3 Molecular markers have been used to select individual plants to create mildew resistant varieties of pearl millet, a cereal grown for foodgrain and straw in the hottest, driest areas of Africa and Asia.

2.3.4 Molecular markers are useful to measure the extent of variation at the genetic level, within and among populations. This can guide genetic conservation activities for crops and livestock, as well as forestry and fisheries.

For example, global surveys indicate that about 40% of domestic livestock breeds are at risk of extinction. Most of these breeds are found only in developing countries, and there is often little knowledge about them or about their potential for improvement. They may contain valuable genes that confer beneficial characteristics such as disease resistance that may be of use for future generations. Modern biotechnologies can help to counteract trends of genetic diversity loss in the food and agriculture sectors.

2.3.5 Molecular markers have been widely used to identify the genetic makeup of organisms and for obtaining their "genetic fingerprint". Such knowledge can be very important in forest management, endangered species conservation, and livestock breeding and tracing.

2.4 How can laboratory techniques help in growing and selecting plants?

2.4.1 Gardeners routinely make new plants simply by planting cuttings from existing ones. Micropropagation, making plants from small plant samples grown in test tubes, is merely a more sophisticated and efficient variant of this technique.

It is often a very effective way of producing very large numbers of nearly identical plants from one individual plant with desired characteristics. This technique is extensively used in hundreds of laboratories around the world for example for generating disease-free banana plants, and has potential applications in forestry.



Work on wheat at the Indian Agricultural Research Institute. Source: FAO

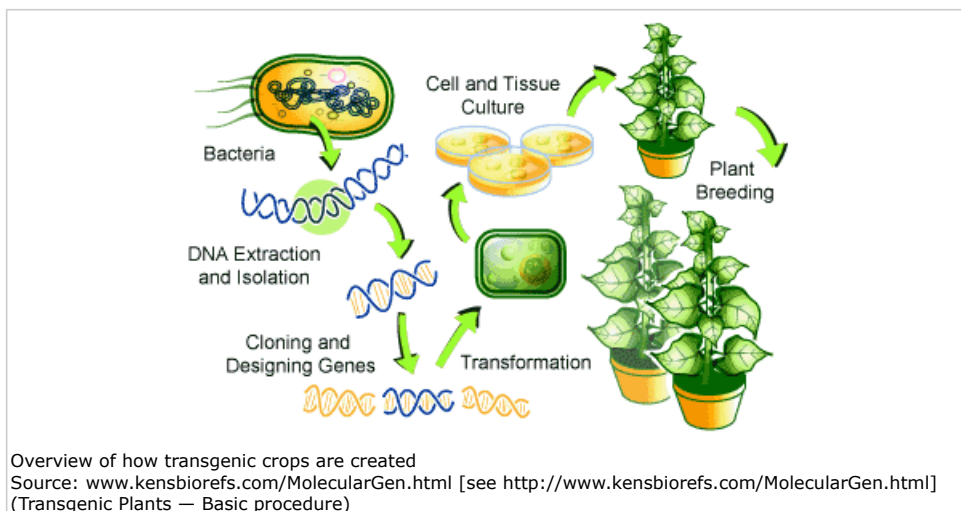
2.4.2 For in vitro selection, plant cells are grown in laboratories under adverse conditions. This allows the selection of cells that, for example, are resistant to diseases or tolerant to herbicides, metals, salt, or low temperatures before growing the full plant. However, in vitro selection is still of limited use for some characteristics like wood quality or stem form in forest trees, since these characteristics only become apparent in fully grown plants.

2.5 How can genetic engineering transfer characteristics from one species to another?

Genetic engineering differs from conventional plant breeding. In conventional plant breeding half of the genes of an individual come from each parent, whereas in genetic engineering one or a few specially selected genes are added to the plant genome.

Moreover, conventional plant breeding can only combine closely related plants. Genetic engineering permits the transfer of genes between organisms that are not normally able to cross breed because they are not genetically compatible. The transferred genes are called transgenes. They can come from another plant species, or even from a completely different organism (e.g., bacterial genes). These transgenes are then replicated and inherited in the same way as natural plant genes.

Genetic engineering of plants usually makes use of a type of bacteria which has the natural ability to transfer DNA to some plants.



When the bacterium infects the plant, it penetrates the plants cells and transfers its modified DNA to the plant.

The DNA may also be introduced by physical means. Carried on microscopic particles of tungsten or gold, the DNA is literally shot into the plant nucleus, using a 'gene gun'. Once the DNA reaches the cell nucleus, it inserts itself at random into one of the host chromosomes and can express the desired character. The genetically modified plant is then grown from the transformed cell.

A number of economically valuable characteristics have been introduced into plants by genetic engineering. Most of the genetically modified crop plants used so far have transgenes that provide resistance to herbicides or insects. To improve crop production and soil management, research is now exploring how to increase the variety of transgenic characteristics to include resistance to drought, heat, cold, acid soils, and heavy metals. These characteristics will increase the range of soils and climates that are able to support agriculture.

2.6 What characteristics can be transferred to plants?

2.6.1 Transgenic plants can provide food with **enhanced nutritional content**. For example, genetically modified "Golden Rice" contains two daffodil genes and one bacterial gene that together result in elevated levels of provitamin A.

Another project involves producing rice with increased levels of provitamin A, protein, and iron. The "protato" is a genetically engineered potato which contains more protein than usual because it carries a gene from the edible South American amaranth plant. In India, where potato is the staple food of poor people, the protato could increase the availability of certain essential amino acids. Opponents of this project argue that potatoes do not contain significant amounts of proteins to start with, so even doubling the protein content would actually only make a small contribution to solving India's malnutrition problem.

Other projects aim to produce plant oils with lower levels of undesirable fatty acids or to reduce allergens in common foods such as peanuts, soybean, and cereals. Trees with a reduced lignin content would be useful for the pulp and paper industry and would lessen the amount of polluting chemicals used in the production processes.

2.6.2 In more than 30% of all arable land, primarily in developing countries, **aluminium can be present in the soil** in a form that limits plant growth. To prevent these harmful effects, the usual approach is to add lime to the soil to reduce its acidity. However, this measure is costly and its benefits are temporary, because the aluminium remains in the soil.

A new approach consists of developing new varieties of plants that are more tolerant to aluminium. For example, rye is four times more resistant to aluminium than wheat. A gene controlling aluminium tolerance in rye was identified and its position on the genome determined. Knowing the location of this gene in rye can help locate it in other crops such as wheat. Thus within a crop species individual plants which are more resistant than others to aluminium could be identified and selected for further breeding. Alternatively, the gene could also be transferred from rye to other closely related species such as wheat.

These techniques could be applied to improve many characteristics in other crop species.

3. Does conventional plant breeding have effects on health and the environment?

In conventional plant breeding, little attention has been paid to the possible impacts of new plant varieties on food safety or the environment. Conventional plant breeding and artificial selection can create gene combinations that would rarely survive in nature. In a few cases, such gene combinations have caused negative effects on human health. For example, a cultivated variety of potato was found to contain excessive levels of naturally occurring toxins.

The potential impacts of conventionally bred crops on the environment or on farmers' traditional varieties have generally not been subjected to regulatory controls. Some of the concerns of gene transfer between domesticated and wild plants that have arisen because of the introduction of genetically modified plants also apply to conventional crops.

Highly domesticated plants are grown all over the world and migration outside cultivated areas has only rarely led to serious problems. Some exchange of genetic material (gene flow) between cultivated plants and their wild relatives has been reported but in general this has not been considered a problem.

4. Are genetically modified plant foods safe to eat?

4.1 Could genetically modified plant foods have health effects?

The question of the safety of genetically modified foods has been reviewed by the International Council of Science (ICSU), which based its opinion on 50 authoritative independent scientific assessments from around the world. Currently available genetically modified crops – and foods derived from them – have been judged safe to eat, and the methods used to test them have been deemed appropriate.

Millions of people worldwide have consumed foods derived from genetically modified plants (mainly maize, soybean, and oilseed rape) and to date no adverse effects have been observed. The lack of evidence of negative effects, however, does not mean that new genetically modified foods are without risk. The possibility of long-term effects from genetically modified plants cannot be excluded and must be examined on a case-by-case basis.

4.1.1 Allergens and toxins occur in some traditional foods and can adversely affect some people leading to concerns that genetically modified plant-derived foods may contain elevated levels of allergens and toxins. Extensive testing of genetically modified food currently on the market has not confirmed these concerns. The use of genes from plants with known allergens is discouraged and if a transformed product is found to pose an increased risk of allergies it should be discontinued. All new foods, including those derived from genetically modified crops, should be assessed with caution.

4.1.2 One concern about food safety is the potential transfer of genes from consumed food into human cells or into micro-organisms within the body.

Many genetically modified crops were created using antibiotic-resistance genes as markers. Therefore, in addition to having the desired characteristics, these genetically modified crops contain antibiotic-resistance genes. If these genes were to transfer in the digestive tract from a food product into human cells or to bacteria, this could lead to the development of antibiotic-resistant strains of bacteria. Although scientists believe the probability of such a transfer is extremely low, the use of antibiotic-resistance genes has been discouraged.

Methods are now being developed whereby only the strict minimum of transgenic DNA is present in genetically modified plants. Some of these techniques involve the complete elimination of the genetic marker once the selection process has been made.

4.1.3 Scientists generally agree that genetic engineering can offer some health benefits to consumers. **Direct benefits** can come from improving the nutritional quality of food and from reducing the presence of toxic compounds and allergens in certain foods.

Indirect health benefits can come from diminished pesticide use, less insect or disease damage to plants, increased availability of affordable food, and the removal of toxic compounds from soil. These direct and indirect benefits need to be better documented.

4.2 How should genetically modified food safety be assessed?

Introduction of new or modified foods, such as genetically modified foods, requires risk analysis since every activity involves risk and in some cases inaction also entails risk.

Several guidelines have been established by national authorities and by the FAO/WHO for food safety assessment of foodstuffs derived from genetically modified plants. In such assessments, the genetically modified food is compared to its conventional counterpart, which is generally considered safe due to its long history of use. They compare to what extent the different types of food can cause harmful effects or allergies and how much nutrients they contain.

Scientists recommend that safety assessment should take place on a case-by-case basis before genetically modified food is brought to the market, since post-market monitoring is more expensive and difficult. The safety assessment process should be transparent, fully documented, and open to public scrutiny, while at the same time respecting the confidentiality of commercial information.

4.3 How should genetically modified foods be labelled in the market place?

Consumers may wish to select conventional foods on the basis of several criteria such as methods of production (e.g. organic or fair-trade food), religious principles (e.g. kosher food), or the presence of known allergens (e.g. groundnuts).

Labelling of foods as genetically modified or non-genetically modified may enable consumer choice as to the process by which the food is produced. However, it conveys no information as to the content of the foods, and what risks or benefits may be associated with particular foods. More informative food labeling, explaining how food has been transformed and what the resulting changes in food composition are, could enable consumers to assess these risks and benefits.

The FAO/WHO guidelines (which are still at a preliminary stage) propose to label genetically modified food when they

1. are significantly different from their conventional counterparts,
2. contain protein or DNA resulting from genetic modification technology, and
3. are produced from, but do not contain, genetically modified organisms, genetically modified DNA, or genetically modified protein.

5. What effects could genetically modified crops have on the environment?

5.1 What direct effects could genetically modified plants have on the environment?

Agriculture of any type - subsistence, organic or intensive - affects the environment, so it is expected that the use of new genetic techniques in agriculture will also affect the environment.

Genetic engineering may accelerate the damaging effects of agriculture, have the same impact as conventional agriculture, or contribute to more sustainable agricultural practices and the conservation of natural resources, including biodiversity.



Farmer in a field of maize in Bolivia
Source: FAO

Although scientific opinion is divided over these risks, it is agreed that environmental impacts need to be assessed on a case-by-case basis. They recommend ecological monitoring to detect any unexpected events once the plants are grown in the environment.

5.1.1 Horizontal gene flow refers to a gene transfer, usually through pollen, from cultivated species to their wild relatives (and vice-versa). This may happen with either conventional or genetically modified plants.

However, many of the world's major food plants are not native to the areas where they are grown and thus lack close wild relatives that would be needed for gene flow to occur. For example, potatoes (which originate in South America) and maize (originating in Mexico) have no wild relatives in Europe. In such cases, horizontal gene flow to wild relatives is impossible. In the USA, cotton and maize have no wild relatives, whereas sunflowers, squash, and radishes do, making the latter possible candidates for gene flow.

In general, gene flow between cultivated plants and their wild relatives is not considered an environmental problem unless it leads to undesirable consequences. Moreover, gene flow from cultivated crops to wild relatives is expected to create hybrids with characteristics that are advantageous in agricultural environments, but that would not thrive in the wild. In the UK, for instance, no hybrid between a crop and a wild relative has ever become invasive.

Future genetically modified plants may be designed to prevent gene flow to other plants. This is important for the co-existence of GM and conventional crops, and may be particularly important for genetically modified plants producing substances of medical or industrial interest. Management strategies to control gene flow include avoiding the planting of genetically modified crops where wild relatives are present, or using buffer zones to isolate genetically modified varieties from conventional or organic varieties.

5.1.2 Plants which carry a specific "Bt" gene produce a toxin that kills insect pests that feed upon them, but is harmless to humans and other species which are not considered insect pests. Bt is used as a natural insecticide in organic agriculture.

A controversy arose about whether pollen from Bt plants could harm beneficial species (such as the monarch butterfly). However, a series of follow-up studies concluded that under field conditions the risk of harm to monarch butterfly caterpillars from Bt maize pollen is very small, particularly in comparison with other threats such as conventional pesticides and drought.

In the field, no significant adverse effects on non-target wildlife nor long term effects of higher Bt concentrations in soil have so far been observed. Yet scientists disagree on how much evidence is needed to demonstrate that growing Bt crops is sustainable in the long term.

Therefore, scientists call for continued monitoring for such effects, and for comparing effects of the Bt gene on the crops with the effect of other current agricultural practices such as chemical pesticide use.

5.2 What indirect effects could genetically modified plants have on the environment?

5.2.1 Scientists agree that the use of conventional agricultural pesticides and herbicides has damaged habitats for farmland birds, wild plants and insects and has seriously reduced their numbers.

Genetically modified crops may have **indirect environmental effects** as a result of changes in agricultural or environmental practices associated with the new varieties.



Farmer spraying pesticide on rice seedlings in Laos Source: FAO

However, it remains controversial whether the net effect of these changes will be positive or negative for the environment, so more comparative analysis of new technologies and current farming practices is still required.

The following paragraphs explore possible environmental benefits:

5.2.2 Using genetically modified crops which are insect resistant because they carry the Bt gene has reduced **insecticide use** on maize, cotton, and soybean. The environmental benefits include less contamination of water supplies and less damage to non-target insects. In turn, this may be beneficial to biodiversity, in comparison to conventional crops that receive regular broad-spectrum pesticide applications. Health benefits to farm workers due to reduced chemical pesticide spraying have been documented in China.

5.2.3 The adoption of genetically modified crops which are tolerant to certain less toxic forms of herbicides, has resulted in a marked shift towards the use of these less toxic forms though total herbicide use has increased. Scientists agree that herbicide-tolerant crops are encouraging low-till agriculture (which limits the use of plows), with resulting benefits on soil conservation. On the other hand greater use of herbicides - even less toxic herbicides - could further erode habitats for farmland birds and other species.

Extensive farm-scale evaluations of the impacts of genetically modified herbicide-resistant crops in the United Kingdom concluded that commercialization of these crops would have a range of impacts on weed vegetation, with consequent effects on the herbivores, pollinators and other populations that feed on it. The observed effects on biodiversity varied for different genetically modified species, with negative effects in sugar beets, positive effects for maize and no effects for oilseed rape. Scientists acknowledge that evidence is insufficient to predict the long-term impacts of such genetically modified crops.

5.2.4 The extensive use of herbicides and insect resistant crops could result in the **emergence of resistant weeds and insects**. This has often occurred as a consequence of conventional herbicide and insecticide spraying. Several weed species have developed resistance to specific herbicides which are extensively used in combination with herbicide-resistant genetically modified crops. Insect-resistant Bt-crops similarly could lead to the emergence of Bt-resistant insects. The extent and possible severity of impacts of resistant weeds and insects are subject to continuing scientific investigation.

5.2.5 New genetically modified crops are being developed that can withstand **environmental stresses** such as drought, salinity, or the presence of aluminum in the environment. They may permit cultivation of soils that are presently of low productivity for agriculture. Scientists agree that these crops may be either beneficial or harmful for society, depending on the crop, the characteristic, and the environment.

5.3 How should these environmental effects be assessed?

The broad consensus is that genetically modified plants should be evaluated using science-based assessment procedures, on a case-by-case basis depending on the species, characteristic, and agricultural ecosystems. The use of genetically modified plants should be compared to other agricultural practices and technology options, in particular to conventional agriculture, which has already had a profound effect on the environment.

Procedures and international guidelines for the assessment of GMOs are well developed for food safety but not for environmental impacts. For instance the FAO/WHO Codex Alimentarius Commission provides an international forum for developing food safety guidelines.

In the absence of international guidelines, environmental impact assessments differ in:

- the interpretation of data and of what constitutes an environmental risk or harm,
- the basis for comparison used: comparing the use of genetically modified crops either with conventional agricultural or with non-cultivated environments,
- the extent to which small-scale laboratory and field trials are valuable and can be used to extrapolate large-scale effects.

The scientific community recommends more research and better monitoring regarding post-release effects of genetically modified crops.

6. What are the implications of GM-technologies for animals?

6.1 What are possible effects of genetically modified animal feed?

Genetically modified crops and enzymes derived from genetically modified micro-organisms are widely used in **animal feeds**. Feed mixtures are principally used for poultry, pigs and dairy cows and contain a range of ingredients, including maize and other cereals and oilseeds such as soybeans and canola. Currently, a significant portion of soybeans, canola, and maize produced is genetically modified.

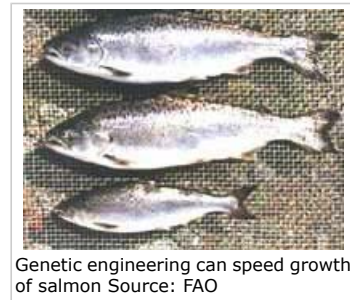
Safety assessment studies in many countries have compared the new genetically modified feeds with their conventional counterparts. These comparisons address, for example, the nutritional composition of feeds as well as their effects on animals and on humans eating the resulting animal products.

Studies have also considered the fate of modified DNA in the digestive tract of the animal. Results indicate that both modified DNA and proteins are rapidly broken down in the digestive system, and no adverse effects have been reported on either growth, body-weight, feed conversion, nutrient composition, or milk production. An FAO review considered it extremely unlikely that genes may transfer from genetically modified plants to disease-causing bacteria. Nevertheless, it advised against using genes which determine resistance to antibiotics that are critical for treating human infectious diseases in genetically modified plants.

6.2 What are possible effects of genetically modified animals?

As of 2004, no **genetically modified animals** have yet been used in commercial agriculture anywhere in the world. However, the possibility of transferring genetically modified characteristics to several livestock and aquatic species is being studied.

Reports addressing those potential environmental concerns recommend that genetically modified animals should be evaluated in comparison with their conventional counterparts.



Genetic engineering can speed growth of salmon Source: FAO

Adverse environmental impacts from escaped genetically modified animals are less likely for livestock breeds than they are for fish. This is because most farm animal species have no close wild relatives remaining and farm animal reproduction is generally confined to managed herds and flocks.

The use of genetically modified animals could also lead to environmental impacts through changes in the animals themselves or in the management practices associated with them. Genetic modifications could for instance reduce the amount of manure and methane emissions produced by livestock and aquaculture species. Furthermore, they could increase their resistance to diseases, which would promote lower antibiotic usage. However, some genetic modifications could lead to more intensive livestock production associated with increased pollution. The question of environmental harm is therefore considered less a question of the technology itself than of the capacity to manage it.

An additional factor that should be taken into account with livestock biotechnology is the possible effect on the welfare of animals. At present, the production of genetically modified and cloned animals is extremely difficult, with high mortality during early embryonic development and success rates of only 1-3%. Moreover, in the genetically modified animals that are born, the inserted genes may not function as expected, often resulting in anatomical, physiological, and behavioural abnormalities.

Therefore, in addition to economic considerations, the possible environmental impacts or effects on the welfare of animals are to be taken into account in livestock biotechnology.

7. Are GMOs regulated by international agreements?

7.1 How is international agricultural trade regulated?

Opportunities for agricultural trade have increased dramatically over the past several years as a result of reforms of the World Trade Organization (WTO) which have mainly centred on reducing tariffs and subsidies in various sectors. The WTO **Agreement on the Application of Sanitary and Phytosanitary Measures** (SPS Agreement), adopted in 1994, establishes that countries retain their right to ensure that the food, animal, and plant products they import are safe. At the same time it states that countries should not use unnecessarily stringent measures as disguised barriers to trade.

The agreement states that countries should use internationally agreed standards and identifies three international standard-setting bodies: the Codex Alimentarius Commission for food safety, the World Organisation for Animal Health (OIE) and the International Plant Protection Convention (IPPC) for plant health.

7.2 Do international conventions address environmental effects of GMOs?

Several international agreements relate to the environmental aspects of genetically modified organisms (GMOs). These include the Convention on Biological Diversity (CBD), the Cartagena Protocol on Biosafety (2003), and the International Plant Protection Convention (IPPC).

7.2.1 The **Convention on Biological Diversity** (CBD) is mainly concerned with the conservation and sustainable use of ecosystems but also addresses environmental effects of GMOs.

The **Cartagena Protocol on Biosafety** was adopted by the CBD and came into force in 2003. The protocol sets out an Advance Informed Agreement procedure for the intentional introduction of species that may have adverse environmental effects. In the case of genetically modified plants, it particularly regulates trans-boundary movement. Such movement requires an advance notification by the exporting party and a notice of receipt by the importing party.



The Protocol details specific requirements for the handling, labelling, packaging, and transportation of genetically modified plants. It also requires registration of all relevant information with the Biosafety Clearing House, an international mechanism established under the Protocol.

7.2.2 The chief purpose of the **International Plant Protection Convention** (IPPC) is to secure common international action to prevent the spread of pests affecting plants and plant products, but it also plays a role in the conservation of plant diversity and the protection of natural resources. Regarding GMOs, the IPPC has identified potential pest risks that may need to be considered, including:

1. new genetic characteristics that may cause invasiveness (drought resistance, herbicide tolerance, pest resistance),
2. gene flow (transfer of genes to wild relatives or other compatible species), and
3. effects on non-target organisms (beneficial insects or birds).

8. Conclusions

8.1 Conclusions on agricultural biotechnology

On the one hand, agricultural biotechnology may be viewed as a complement to conventional agriculture. It is a scientific tool that can aid plant breeding programs and the conservation of genetic resources, as well as improve the diagnosis and treatment of plant and animal diseases. On the other hand, it may be viewed as a dramatic departure from conventional agriculture, since it enables the transfer of genetic material between organisms that would not normally crossbreed.

In fact, agricultural biotechnology is both at the same time, since it cannot stand on its own. To achieve useful results it needs both classical plant breeding methods as well as the information derived from genomics. Agricultural biotechnology has international implications and may become increasingly important for developing countries.¹ However, it arose in developed countries, which continue to dominate this technology. Thus research tends to

focus on crops with relevance to developed countries rather than to developing countries, which usually do not have the research funding and breeding programs that are necessary for GM technology.

¹ India, China, Argentina, and Brazil are some of the countries that have active biotechnology development programmes.

8.2 Conclusions on environment and health effects

To date, countries where genetically modified crops have been introduced in fields, have not reported any significant health damage or environmental harm. Monarch butterflies have not been significantly affected. Pests have not developed resistance to Bt. Some evidence of herbicide tolerant weeds has emerged, but superweeds have not invaded agricultural or natural ecosystems. On the contrary, important social and environmental benefits are emerging. Farmers are using less pesticides or using less toxic ones, reducing harm to water supplies and workers' health, and allowing the return of beneficial insects to the fields.

Meanwhile, technical or management solutions have been found to address some of the concerns associated with the first generation of genetically modified crops, such as antibiotic resistance.

However, the fact that no negative effects have so far been observed does not mean that such effects cannot occur. Therefore scientists encourage further research.

FAO supports a science-based evaluation system that would objectively determine the benefits and risks of each individual GMO. This calls for a cautious case-by-case approach to address legitimate concerns for the biosafety of each product or process prior to its release. The possible effects on biodiversity, the environment and food safety need to be evaluated, and the extent to which the benefits of the product or process outweigh its risks assessed. The evaluation process should also take into consideration experience gained by national regulatory authorities in clearing such products. Careful monitoring of the post-release effects of these products and processes is also essential to ensure their continued safety to human beings, animals and the environment.

"Science cannot declare any technology completely risk free. Genetically engineered crops can reduce some environmental risks associated with conventional agriculture, but will also introduce new challenges that must be addressed. Society will have to decide when and where genetic engineering is safe enough" (FAO 2004).

Annex

Annex 1:

Table 1: An agricultural technology timeline

Technology	Era	Genetic interventions
Traditional	About 10 000 years BC	Civilizations harvested from natural biological diversity, domesticated crops and animals, began to select plant materials for propagation and animals for breeding
	About 3 000 years BC	Beer brewing, cheese making and wine fermentation
Conventional	Late nineteenth century	Identification of principles of inheritance by Gregor Mendel in 1865, laying the foundation for classical breeding methods
	1930s	Development of commercial hybrid crops
	1940s to 1960s	Use of mutagenesis, tissue culture, plant regeneration. Discovery of transformation and transduction. Discovery by Watson and Crick of the structure of DNA in 1953. Identification of genes that detach and move (transposons)
Modern	1970s	Advent of gene transfer through recombinant DNA techniques. Use of embryo rescue and protoplast fusion in plant breeding and artificial insemination in animal reproduction
	1980s	Insulin as first commercial product from gene transfer. Tissue culture for mass propagation in plants and embryo transfer in animal production
	1990	Extensive genetic fingerprinting of a wide range of organisms. First field trials of genetically engineered plant varieties in 1990 followed by the first commercial release in 1992. Genetically engineered vaccines and hormones and cloning of animals
	2000s	Bioinformatics, genomics, proteomics, metabolomics

Source: Adapted from van der Walt (2000) and FAO (2002a)

Source: FAO "The State of Food and Agriculture 2003-2004"

Chapter 2: What is agricultural biotechnology?

Section Understanding, characterizing and managing genetic resources [see <http://www.fao.org/docrep/006/Y5160E/y5160e07.htm>]