1 Background on GMOs

1.1
Basic Facts About GM Crops

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Genetic engineering of crops is a new addition to traditional plant breeding. It is part of our quest to grow more and better food for our growing population. The total area under genetically modified (GM) crop cultivation has been steadily expanding with, however, a marked slowdown in the last few years. Soybean, corn and cotton are the most extensively cultivated GM crops. Europe grows less than 0.5% of the world's GM crops, mainly because of the de facto moratorium imposed on GM crops in Europe until 2003 and the refusal of the European consumers to buy GM products. Currently grown GM crops mainly benefit the farmer, not the consumer. Future uses of GM crops may bring more direct benefits, such as improved taste and quality, to the consumer. All food, whether GM or non-GM, might have certain risks of containing allergic or toxic compounds and all novel foods should be tested for possible allergic and toxic effects on living organisms. Some environmental groups are also concerned about the effect of GM crops on the environment. Most of all they are worried about the unknown effects these crops may have on our environment, and the difficulty of controlling GM crops once they are released into the environment. The discussions about GM crops and food are complex and include issues of choice, globalisation and alternative ways to grow crops. Europe is going ahead with comprehensive labelling and tracing of GM crops and their products. However, even if there were such standards, there is currently no mechanism to implement and enforce these standards on the international market. This first overview chapter is based on the film "Genes on the menu", enclosed as a CD with this book.

1.1.1
Where Does Our GM Food Come From?

The total global area of GM crops exceeded 60 million ha in 2002. In the developing countries, more than 15 million has are under cultivation with GM crops. USA growth nearly 70% of the total, followed by Argentina, Canada and China (for more informations, see Sect. 2.4.1).

Soybean, maize and cotton are among the GM crops that are most extensively cultivated. Soybean represents over 60% of the total GM crop area. These crops were developed to allow better management of weeds and pests. They also include foods like tomatoes and potatoes. In Europe, however, it is not currently possible to buy fresh GM produce. Even in North America, most fruit and vegetables are not yet available as GM products.

Europe grows less than 0.5% of the world's GM crops, mostly maize for animal feed. The European Union has strict limitations on the planting of GM crops. GM crops that have been authorised can be grown, but apparently there is no market to sell EU-grown GM crops. The challenge of coexistence with organic and conventional farming complicates the issues further. European countries do, however, import GM crops and food products from abroad. Thousands of tons of GM soybean seed are imported to Europe as feed for livestock. Soybean also enters our markets as part of many processed food products. Background on current GM crops can be found in Sects. 2.1 to 2.4.

The European Union has put in place new rules to govern the use of genetically modified organisms (GMOs), including GM crops. When foods contain, consist of, or are produced from GMOs, they have to be labelled as such. However, a provision is made for accidental contamination of food sources by GMOs. In such cases, conventional food destined for human consumption is labelled as GM only if it contains more than 0.9% GM ingredients. Thus food products containing less than 0.9% of GM ingredients do not have to be labelled as GM food. As soybean is used in many processed foods, it is likely that much of the food we eat today already contains some GM ingredients although it is not labelled as GM food. In addition, food originating from animals fed GM crops does not need to be labelled as transgenic. The GMO debate revolves around many inter-linked issues and perspectives. All must be taken into account at a decision-making level. Nevertheless, GMOs are a reality of today's market. The need is thus for traceability and labelling to ensure safety and choice, as indeed has been proposed and enacted in Europe. However, labelling does not say anything about the safety of the product: if the product is not safe it will not be allowed onto the market. It also gives consumers the choice of deciding whether or not to purchase GM products for personal use. The main purpose of tracing and labelling GM food in Europe is to identify the precise origin of the food product, so that if a problem arises it can be dealt with quickly. Traceability and labelling of GMOs will cost millions of euros per year. Some propose it may be better to have the regulatory authorities simply decide whether the foods are safe or not and allow retailers to choose whether to label or not. For information about GM product traceability and labelling please see Sects. 3.3 and 4.1.

1.1.2
What is Different About GM Crops and Food?

Man has been modifying plants for over 10,000 years. In plant breeding, a large number of genes are mixed by crossing different plant varieties, and after subsequent screening, plants with the most desirable characteristics are selected. In genetic engineering, only one or a few selected genes from other organisms that have been previously studied are added to a specific living plant cell that can be regenerated into a whole plant (see also Sect. 1.2).

Potatoes are a good example of our breeding efforts. Over the centuries, traditional plant breeders have turned the wild potatoes still found in South America into the wide range of potato varieties we can buy today. Because of these efforts, potatoes can today be grown around the world. These potato varieties are very different from their wild cousins. They have been genetically modified through traditional plant breeding. Every variety of potato differs in its genetic material, the DNA. Sections of DNA form genes that give instructions how to make different proteins. It is primarily the proteins that determine the exact properties of the plant.

A genetic engineering procedure where a gene from one, sometimes unrelated, organism is transferred to another can give a plant a new property, like resistance to insect or virus attack and tolerance to herbicides. The Bt potato, for example, contains a gene from a soil bacteria, *Bacillus thuringiensis*, that makes potatoes resistant to the Colorado potato beetle.

Thus introducing new genes, using the tools of genetic engineering, is a targeted approach for improving plant characteristics. The use of these genes, or transgenes as they are sometimes called, should be a more predictable approach than traditional plant breeding where thousands of unknown genes are exchanged. Unlike traditional plant breeding however, the approach is new, can involve gene transfer that does not occur naturally and has not been tested for long-term side effects.

1.1.3 Why do Some People Worry About GM Crops?

When dealing with new technologies, it is not surprising for the public to be concerned and feel that they do not have much control over the new developments.

Results from the Eurobarometer (55.2, Spring 2001) dealing with public perception of GM food, showed that at least two thirds of those surveyed thought GM food was dangerous to eat, regardless of their education, sex or age. A quarter of the population was unsure about the dangers. Interestingly, the opinion was almost evenly split when asked whether the media over exaggerated the dangers. However, nearly 70% of people asked did not want to eat GM food. Almost everyone wanted the right to choose whether or not to eat GM food and agreed it should be introduced onto the market only when scientifically proven safe.

The implications of these results are that:

- The public overestimates their knowledge of GM food (current GM food is safe to eat).
- Although education did somewhat increase acceptance of GM food, the % of people who rejected GM food was surprisingly similar regardless of their educational background.
- The public seems to be misinformed about the procedures of food approval. All GM products have to pass though extensive scientific testing procedures. Yet the public on one hand feels that GM food is not safe and on the other hand would accept GM food on the market if proven to be scientifically safe.

- It seems that there remains an information and communication gap between the public, risk managers and decision makers. This gap has most likely arisen because the decision-making process is not fully transparent to the public and the public does not trust the process of getting the products onto the market.

The public may thus perceive new biotechnologies to be riskier than they actually are. In addition, the European public mistrusts governmental institutions to protect the interests of the public and feel that it is being left out of the decision-making process. These conclusions may be, however, specific for Europe and be to some extent related to the public's experiences with institutional handling of food-related scandals such as the BSE outbreak and other recent food crises in various European countries. The issues of public perception of GM crops are dealt with in Sects. 4.3 to 4.6.

Another public concern is the problem of intellectual property rights and monopolies. Some people are worried that parts of our common heritage may become the private property of an individual or a large company.

1.1.4
Why Use GM Crops?

Current usage of GM crops mainly benefits the farmer. Insects and weeds can do great damage to crops and thus negatively affect the income of a farmer. For example, the Colorado potato beetle can, within days, destroy a potato field and endanger the livelihood of a farmer. GM Bt crops have an in-built defence mechanism against this pest, where the protein made from the inserted gene disrupts the insect's digestive system. The advantage of planting Bt crops is that it can reduce the use of insecticides. This means less runoff into the environment where insecticide pollution can cause damage to other living organisms.

The claims that Bt crops and useful insects will be killed in greater numbers than with other treatments have so far not been substantiated, although resistance to pest control is acknowledged to be a question of time. Refuges containing non-transformed plants must now be planted around GM crops to reduce selective pressures for development of pests resistant to, for example, Bt toxin.

Future uses of GM crops may have more direct benefits for our society: new foods may be created that are better-tasting, contain specific ingredients to enhance our health, or manufacture life saving compounds. These functional crops will differ significantly in content and metabolism from the original non-GM plants and will need to be extensively tested prior to general release. Details of current and future benefits of GM crops are discussed in Sects. 2.4, 5.1, 5.2 and 5.3.

1.1.5
How Does the Body Deal with GM Food?

Our bodies use exactly the same processes to digest GM and non-GM food. We eat millions of molecules of protein and DNA at every meal. What happens when we eat a potato chip made from a pest-resistant potato? It is the job of the digestive system to release molecules from the food we eat. Once inside the body, the potato chip, like any other food, is gradually broken down into smaller and smaller pieces by digestive juices. It is in the small intestine where many of the molecules released from the potato chip are absorbed into the blood. The DNA, which contains the instructions for the synthesis of a specific protein, and which also makes the GM potato pest resistant, is treated the same way as all the other potato DNA.

However, certain proteins in all foods can be a potential health risk. This is true both for GM as well as non-GM food. One way of avoiding health risks like an allergic or toxic reaction is to test foods before they come to the market. Indeed, understanding safety issues, their definitions and limitations is in itself complicated (see below and Sect. 3.5, 3.6 and 4.5).

1.1.6 How are GM Foods Tested?

Initial work growing genetically engineered plants is carried out in a laboratory where the researchers must follow strict safety rules set out by government authorities. GM plants are grown to full size in growth chambers and contained greenhouses under conditions where they can be controlled and monitored. When scientists and authorities are satisfied with the test results, small scale planting can be carried out in the field. These so called enclosed plot trials usually run for 3 years and are followed by large scale open field experiments. The GM product can enter the marketplace only if it complies with appropriate food regulations. It takes approximately 10 years from the beginning of the first experiment until the transgenic cultivar is marketed and sold to the farmers.

The European novel food regulation, for example, requires GM crops and their food products, as well as all other foods new to the European market, to go through extensive safety testing procedures. However, scientists know very little about the risks associated even with non-GM food. It is possible to argue, on the basis of experience and selection, that today one can consider the non-GM food we eat as being generally safe. With GM food, it is not possible to make such a statement as the products have been on the market for only a short period of time.

GM foods are analysed to make sure they do not contain substances that might cause toxic or allergic reactions. Toxicologists play an important role in this part of risk assessment. If a toxicologist is uncertain of the health consequences of a novel food being placed on the market, animal or human trials may need to be carried out before the product is released to the public. Tests like these help experts decide whether foods are safe for the consumer. Insect-resistant and herbicide-tolerant crops have been tested this way before they passed as safe for human consumption. All the currently marketed GM crops and food products can be said to be substantially the same (equivalent) as the non-GM controls.

Experts are now concerned with deciding whether or not to allow onto the marketplace second and third generation GM food products, where plant metabolic processes are manipulated,. In these products, the metabolism of a plant is changed to such an extent so that it is no longer substantially equivalent to the original, non-GM plant. For more information on the topic of regulating food safety, please see Sects. 3.3, 3.4 and 4.2.

1.1.7
What are the Effects of GM Crops on the Environment?

The public has four main concerns: that GM crops will create superbugs, superweeds or reduce biodiversity, but above all, they are worried about the irreversibility of GM crop releases. They are concerned about the environment in general, but are generally not opposed to using genetic engineering in self-contained facilities. They are primarily worried that in the open environment pollen from transgenic crops can pollinate other related plant species and result in unforeseen permanent effects on the environment and biodiversity.

Pollen is carried mainly by wind or insects. The distance pollen can be carried varies with the size of the pollen, wind conditions and how far insects can fly. Using the potato as an example again, in Europe and North America there are no wild relatives of the potato. In South America, where potatoes originate, the situation is entirely different. There, potatoes could cross with their wild relatives. After crossing, these plants would produce seeds containing the new genetic information. New genes could then spread to the wider population. We must take great care not to add any new genes to local plant species because in these centres of origin, the local plants serve as the genetic pool to create new plant varieties. This may require setting up buffer zones, where planting of crops (GM and non-GM) related to the wild relatives, is prohibited. The same is true for example of maize that originates in Central America.

Even outside the centres of origin, great care needs to be exercised when releasing GM crops into the environment because there is a danger of transgenes drifting from one plant population to another. This has happened in Canada with rapeseed and has led to accumulation (stacking) of various herbicide-resistance genes in one rapeseed variety. The concerns about gene "pollution" holds true, however, for both GM and non-GM crops. Thus if cultivated crops, both GM and non-GM, cross with their wild relatives, there could be the danger of creating superweeds resistant to herbicides.

Now, because we can trace individual agronomically important genes in GM crops, the study of gene persistence in wild populations has expanded substantially. The assumption at present is that genes that are valued in cultivated crops will not likely persist in wild populations if they are not seen as an advantage to the wild population. For more information on this topic please see Sect. 2.5.

1.1.8
How are Public Opinions Formed?

Different interest groups use a variety of tactics to get their viewpoints into the public arena, either for or against GM crops. The way the public sees plant biotechnology is often determined by images of activists, dressed in white protective suits, destroying crops. Many people remember this as something dangerous and connect it with the new technologies. Even if people knew the full story, they still may have concerns. The majority of people in Europe are uneasy about GM crops.

For many people, attitudes to new technologies are formed in part by their inner moral beliefs. Here, the views of the church can be important. Interestingly, the Catholic church is not against GMOs per se. The Pope and the Church have not stated that GMOs are intrinsically bad or that they should not be grown. They believe a great deal of caution should be exercised to be sure that there are no risks for human health. There has not been any theological condemnation of manipulating living organisms (apart from genetically manipulating mankind itself). The views of other religions or groups may differ depending on the circumstances. For example, if a gene from a pig is introduced into a plant, certain religions may reject the food as unclean. However, the issues of GMOs have transcended moral and safety considerations. They have become part of the social and globalisation, including monopoly, issues, and debates. Sections 4.3, 4.4 and 4.6 address the topics of public opinion, opinion formation and moral attitudes.

1.1.9 What GM Products Can be Expected?

The first commercial products of genetic engineering were plants resistant to pests and weed killers. It is mainly farmers that reap the benefits. Now, researchers in Europe and many other parts of the world are developing new products designed to be of direct benefit to the consumer. These are the so-called second and third generation GM products. The development of new products is driven by industry, available methodologies, scientific curiosity and social need. Areas under active research include plants that are resistant to high salt content in the soil or to drought. To succeed, researchers need to add several new genes to the plant. Other research involves trying to change what happens inside the plants themselves: their metabolic pathways. Major efforts are going into creating foods designed to improve our health or to prevent diseases. For example, tests are underway on a GM rice designed to make a vitamin A precursor to supplement the diet of people deficient in vitamin A. Many of these research advances may be used in the developing world. Future uses of GM crops will be for what is termed molecular farming – using plants as bioreactors to produce, amongst others, medical products and GM foods that directly benefit the consumer in terms of price, taste, health and extra quality. For more information, please see Sects. 2.1 to 2.4 and 5.1 to 5.3.

1.1.10 Can GM Crops Help the Developing World?

For developing countries, research decisions depend on local priorities and are often a question of need rather than choice. Many companies do not consider poor developing countries as a target for their products, nor would they develop products just for these markets. Indeed, it is not the mandate of companies to help the developing world. In these smaller and poorer markets most product development is carried out by public institutions. There, the trend is towards the production of GM crops with improved quality traits such as salt or drought tolerance to improve the crop yields or increase the use of low quality land for cultivation. In other parts of the world, pest control is a major problem. Using chemicals to control pests may create risks to wildlife and to human health and is relatively expensive. Poor instructions along with insufficient training are the main problem. These problems, combined with poor storage conditions, can cause major pollution. Chemical contamination of land is a major tragedy in the developing world. Pest-resistant plants are one way of cutting down on the use of chemical sprays. Genetic engineering, however, cannot offer a complete solution to complex problems, whether natural or man-made.

Sometimes, low technology solutions in developing countries can be just as effective or more appropriate to tackle a problem. The solutions can differ from country to country. The solutions can range from better education of farmers, efficient use of water (for example, drip irrigation), better infrastructures to bring produce to the market place, better storage facilities (in some countries more than 20% of the produce is lost during storage) and using local crops rather than planting imported crop varieties. The issue of GM crops and the developing world is addressed in Sect. 5.3.

1.1.11
Possible Alternatives to GM Crops

The overall aim of agriculture today is sustainable land use and sufficient food production. This primarily means reducing energy inputs into producing food while at the same time treating the environment with respect. GM crops are only one approach to achieving sustainable agriculture. Other approaches include conventional agriculture, integrated farming, low-input farming and organic farming. The latter methods are becoming very important for farming as well as being appealing to consumers. In Germany, for example, the aim is to have 20% of agricultural land under organic cultivation within the next decade. Organic farming is based on respect for nature and avoiding stress situations for plants by balancing the needs of microorganisms living in the soil with those of the plants and the insects that feed on the plants.

Instead of chemicals, organic farmers use biological methods to control pests. A common way is to release natural enemies of the harmful insects. Bt toxin and other pesticides that are extracted from natural materials can be used by organic farmers. In GM crops, the active ingredient of Bt is produced by the plant itself. However, organic farmers object to the use of GM crops as being unnatural.

The decision as to which agricultural approach to use (whether GM, conventional or organic), should depend on comparing the alternatives for a specific area and the objective. This analysis should be based on a detailed risk–benefit analysis that includes health, environmental, social and economic dimensions.

The best alternative, or combination of alternatives, should be used to solve a given problem.

The decisions concerning what and how to farm are thus influenced by many factors, some preventing the combination of various approaches, others encouraging them. It is up to the decision makers and governmental organisations to encourage, monitor and enforce the proper agricultural practices. The topic of coexistence of GM and organic farming can be found in Sects. 2.5, 3.5 and 4.1.

1.1.12 Conclusion

One problem for decision makers is that there are no agreed upon international standards for assessing the risks of GM crops and GM food. Different countries base their judgements on different sets of questions and not all countries have access to good testing facilities.

In the USA, decisions are based primarily on scientific judgements about safety. This approach means that GM developments are moving ahead quite fast but if something goes wrong, guilty parties may be sued. This, combined with ensuing negative publicity, functions partly as a mechanism to ensure "honesty" in their business community. Europe's precautionary principle tries to pre-empt unwanted consequences. The precautionary principle is a decision-making tool that helps to arrive at decisions in the absence of hard scientific data. This allows decision makers to proceed cautiously with GM crops and food. Their decisions are based on social considerations as well as the available scientific evidence. Without an international agreement on standards, food producers face real problems in developing and selling GM products to countries in other parts of the world. Even if international standards can be agreed upon, there is no mechanism to enforce them. This is the real challenge for the decision makers. These complex issues are discussed predominantly in Sect. 4.2.

1.1.13 Information Sources

Parsley GJ (2003) New genetics, good and agriculture: scientific discoveries-societal dilemmas. International Council for Science. The full text can be downloaded from http://www.doylefoundation.org

Visions Unlimited Medien GmbH, Genes On the Menu. For more information, email: VUMedien@AOL.com. A CD version of the film is enclosed with this book