A scientific and ethical discussion regarding genetic modification of plants

Eudoxas Policy Study #6

Eudoxa Report series number 6: A scientific and ethical discussion regarding genetic modification of plants

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The Eudoxa Think Tank publishes this series of policy studies. They address issues that are current or will be in the near future. Eudoxa studies are in depth studies on how emerging technologies will impact our culture and our society

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About Eudoxa

The Eudoxa think tank is a think tank based in Stockholm, Sweden. The main focus of the group is explaining the cultural impact the cultural impact of emerging technologies integrating the analysis with classical free-market ideas and dynamist thoughts of experimentation, innovation and decentralization.

We work for a diverse society based on a strong moral foundation of individual rights, where individuals have the right to utilize modern technology and medicine according to their own moral judgement. We believe this foundation promotes tolerance and acceptance that will tie our society together, not break it apart. The inspiration behind our vision is a firm belief in individual liberty, free enterprise, a limited government and that ideas have impact on our society.

Eudoxa currently has staff working out of Stockholm, Sweden and Kansas City, Missouri giving them the advantage of being able to approach both the European and American market with a comprehensive perspective drawn from experiences from both continents.

Preface

Mankind has during many thousands of years changed the genetic setup of plants in order to achieve better harvests. Modern genetic methods are an extension of traditional breeding methods, which enable us to create new varieties of plants that have improved resistance against vermin, produce enhanced harvests, are more nutritious and reduce the strain of agriculture on the land. Plant improvement via modern genetic methods means that a few genes are altered under laboratory circumstances and intensive studies are performed on the new breed of the plant. In contrast, traditional plant improvement mingles or mutates thousands of genes in order to achieve a positive result by chance. The moral arguments that man cannot play God are built upon a misunderstanding of natural science. Genes are modified constantly in nature via biological processes.

Although many millions of people have eaten genetically modified food for many years, there is still no indication that it would be harmful to the consumer. Still, both consumers and politicians in the EU are very skeptical towards genetic modification of plants. This is in large parts due to myths spread by various groups that oppose these technologies, either because they have economic interests to defend or because they have a dogmatic view on nature and science.

This report, produced by the Eudoxa think tank, considers the debate regarding genetic modification of plants from both a scientific and ethical perspective. We hope that this report shows that altering the genetic content of plants is nothing mystical or abnormal.

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Brief history and introduction

In its early forms, genetics can be said to be nearly as old as the human civilization. Selective breeding followed shortly after domestication of animals such as dogs, horses and oxen. Artificial pollination is described in Assyrian relief art, dated to approximately 800 B.C. And in Roman times plant grafting and animal breeding were common. In the 19th century, time was ripe for the discoveries of Charles Darwin, who described the mechanisms of evolution in *The Origin of Species* in 1859. Shortly afterwards, Gregor Johann Mendel demonstrated the statistical patterns of heritance.

In 1909, the Danish botanist Wilhelm Johannsen coined the term "gene" from the Greek word meaning "to be born". Research during the first half of the 20^{th} century finally gave birth to what is referred to as modern genetics. A major step towards the extensive knowledge in genetics that we have today was taken when James Watson and Francis Crick proposed the double helix model of DNA in 1953. Like in other disciplines, basic research paves the way for applied research and in the end for inventions and benefits for society. As a result of research in genetics, significant improvements have been achieved in the fields of medicine and agriculture.

Genetics is about life. It therefore touches areas such as ethics, theology – and politics. Charles Darwin is still not accepted by many religious communities and modern applications of genetics have met stiff resistance in many countries. A lot of people have a picture of genetics from science fiction movies, which frequently present a (mildly speaking) distorted picture of reality. This report will present some basic facts in the field and discuss scientific and moral aspects of agricultural applications of genetics.

Genetics, biotechnology and food

As mentioned above, intuitive knowledge on heritance was early applied for breeding of animals and improvement of plants. This involved (and still involves) massive shuffling and mixing of genes, sometimes from different species. In this process, spontaneous or induced mutations have contributed to minor and major improvements. All races of today's domesticated animals are the result of many centuries of breeding, mixing of genes and many mutations.

The process of breeding is selective. If and only if the offspring has desirable properties it is kept and used for further breeding. The principles for improvement of plants are similar. Cross pollination, random mutations and selection for many generations have yielded the crops that are used in "traditional" agriculture today.

Genes are present literally everywhere in biological matter. Each time we eat a tomato we are eating maybe around 800 000 000 000 000 individual genes[1]. But what are genes? Genes are strings of DNA that encode for a multitude of different proteins, which serve as for instance building blocks and enzymes in the cell. Proteins control most of the biological activity in all cells and genes in turn control the production of proteins.

Is it unnatural to alter genes?

Genes are not only altered in laboratories. Modification of genes occurs regularly in all living organism. One way in which genes are modified is natural mutations. Natural mutations occur in all living organisms and do not have to be caused by radiation or any unnatural phenomena. In fact, each new human has on average 50-100 mutations in their DNA.

In nature, it is not only common that genes are altered, but also that they are passed along from one species from another. Many viruses insert their DNA into their host cells when they infect them, and this DNA is sometimes passed along to the offspring. Some viruses can insert themselves into one organism, “pick up” a piece of DNA and later on pass this DNA to another organism.

In addition, microorganisms have developed sophisticated mechanism in which they pass genes to each other, even among different species. In fact, the bacteria *Agrobacterium tumefaciens* has developed a mechanism where it inserts a gene into a plant in order to direct the plant to make a hollow

Although DNA strings are to a high extent conserved from generation to generation, they can also change according to several natural processes. In 1977 scientists discovered that *Agrobacterium tumefaciens*, known to cause crown gall diseases in many fruit plants, transfers and integrates its genetic material into plant DNA. A few years later, this discovery was used for construction of the first transgenic plants, where one gene (or a small cluster of genes) was transferred into a plant with *A. tumefaciens* as a vehicle.

A *genetically modified organism* (GMO), is a transgenic organism (microorganism, plant or animal) which has acquired one or more genes under controlled circumstances. It is a complicated technique, but applications have been on the market for many years now. The most important improvements so far involve reduced dependence on toxic chemicals or improved nutritional value of crops. In the United States and in Asia, thousands of farmers cultivating for instance wheat, maize, soybeans and cotton, prefer to buy genetically modified seeds than to constantly struggle with weeds and insects.

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[1] Assuming each tomato cell is spherical with a radius on 25 μm, that each tomato is spherical with a radius of 5 cm and each cell contains on average 100 000 individual genes.

However, the technique to insert genes into organisms is controversial. A lot of people understandably find it difficult to penetrate the scientific language connected with these products and prefer not to consume them. Therefore, it appears worthwhile to present the most widespread applications and to discuss some common concerns about transgenic plants.

What are we eating?

> ”Organizations such as Greenpeace and Friends of the Earth have long understood the power of icons, imagery and suggestion in manipulating the general mood.”
>
> Financial Times editorial, 20 February 1999

When discussing genetically modified plants it is necessary to look at the specific applications. What are we eating, and why? In what ways, exactly, are genetically modified crops altered? Below, the two by far most common applications are described. It should be kept in mind that usually one or a few genes are added and/or removed. Given that higher organisms can have hundreds of thousands of genes, and that genes are altered by natural processes all the time. The fact that one gene or a cluster of genes are added does not alter the nature of a plant significantly. A genetically modified tomato is still a tomato.

Greenpeace Nordic has a tomato with a human embryo inside it as their “logo” for their anti-GMO agenda. The picture is not only distasteful (and very provoking for pregnant women), it is also very unscientific. Even if human genes were inserted into a tomato, which is not the case, they do not represent human life and would certainly not create a human embryo. To imply it demonstrates either complete ignorance of science or contempt of the public. Genes are not life. They are strings of DNA that encode proteins. From a scientific perspective a gene from a human plays a small role in human life only of it is expressed in a human cell in human tissue.

Many genes that we have in our bodies are in nearly identical forms present in thousands of other species. We even have many genes in common with plants cells. This is not a coincidence, since the chemistry of life is similar in all living organisms and we have all evolved from a common ancestor.

Glyphosate tolerance

One of the most widespread applications of genetically modified plants is giving them tolerance to glyphosate. Glyphosate is a weed-killer, which inhibits formation of aromatic amino acids in targeted plants and is the active substance in a product with the commercial name "Round up".

However, a protein produced by some bacteria can metabolise glyphosate and the gene expressing this protein has been transferred to several plants, for instance soybean and wheat. This concept is practical for farmers, since they have a weed-killer that kills everything *except* the one being cultivated.

Glyphosate is *less* toxic than most traditional weed-killers and also *less* persistent in nature. No test has indicated that it would be carcinogenic or otherwise harmless to humans exposed to residual concentrations in harvested crops. But there are still some concerns about the effects of glyphosate on non-plant species, when present in high concentrations. Other ingredients (than the active one) in Round-up have also been debated.

It is ironic though, that it is the *chemical* aspect of the concept that has been criticized. No negative effects have been suggested for the genetic modification itself. It is true, however, that the genes can spread from for instance from rape to charlock. That a cultivated crop and a common weed are so closely related that they can cross pollinate and transfer genes to each other is, however, to be considered as an exception. (See "*the containment issue*" below.)

Bacillus Thuringiensis

Many types of vermin feed on plants, but in cultivation of for instance maize the most serious problems are caused by insects. The traditional way to combat insects is to use insecticides, which may have undesirable side effects if used incorrectly.

Some bacteria defend themselves against digestion by insects in a very sophisticated way. For instance *Bacillus thuringiensis* produces the insecticidal protein ∂-endotoxin. In its original form it is inactive and harmless, but insects digest it in a special way that makes it toxic.

Genetic modification has transferred the ability to produce ∂-endotoxin to for instance maize, which provides the plant with an efficient defense against insects. This means that the farmer does not depend on any synthetic chemical in order to defend his crops against insects.

The ecological effects of these crops have been debated (see *Ecological effects* below), but it is widely accepted that the use of *Bt*-engineered crops is harmless to humans and reduces the need for pesticides in agriculture.

Is it safe to consume?

> "The responsible genetic modification of plants is neither new nor dangerous. Many characteristics, such as pest and disease resistance, have been routinely introduced into crop plants by traditional methods or sexual reproduction or cell culture procedures. The addition of new or different genes into an organism by recombinant DNA techniques does not inherently pose new or heightened risk relative to the modification of organisms by more traditional methods, and the relative safety of marketed products is further ensured by current regulations intended to safeguard the food supply. The novel genetic tools offer greater flexibility and precision in the modification of crop plants."
>
> The Declaration of Support for Agricultural Biotechnology, signed by 3,400 international scientist

From a philosophical point of view, the word "safety" does not exist. To show that water would be safe to consume would require extensive research and the outcome would only show that water is *probably* safe to consume. Random effects could appear that would indicate the opposite. That being stated, it does indeed make sense to thoroughly investigate possible effects of any new product intended for human consumption, including transgenic plants.

Genetically modified plants are thoroughly tested by the companies that produce them, but the crops must not be introduced to the market until they are approved by the authorities. In the United States, all new products intended for human consumption (including food, chemicals and drugs) are tested by the Food and Drug Administration, a widely respected institution, known to defend interests of the consumer.

It is also worth underlining that several transgenic crops have been on the market now for decades and are today being consumed by hundreds of millions of people. And it has so far not been possible to show any negative effects for consumers. This does not mean that the issue is closed. All new products must be

Can GM food cause allergies?

Some people believe that genetic modification of foods can cause allergies. There is nothing in genetic modification itself that causes allergies, but if a protein that causes allergies in one plant is expressed in another, it will probably have the same affect in the new plant.

This was the case when US scientists in 1997 inserted a gene from a Brazil nut into soybeans to make them more nutritious. The genes also passed on the property of the Brazil nuts that causes allergies. Since genetically modified foods go through rigorous testing before being marketed, the allergenic properties of the new breed of soybeans were discovered and the project was abandoned.

tested individually and if a product (transgenic or not) would turn out to be harmful for humans it would be withdrawn from the market immediately.

Greenpeace Nordic in 2004 stated that *Bt* modified maize was "unhealthy", referring to a report by the British scientist Arpad Pusztai. The reality was that an extensive study had been carried out on rats, which had been fed with *Bt* maize, and a large number of parameters had been measured according to the common procedure for animal testing. Some parameters differed, which is considered normal in this kind of test. A board of experts at the EFSA (European Food Safety Agency) judged that the product was safe for consumption and did not alter its conclusions.

The report by Dr Pusztai was criticized for being biased. Still it did not provide any evidence for Greenpeace to claim that the tested product would be "unhealthy".

Is it safe to cultivate?

In principle, all human activity is connected with effects of some kind on the surrounding environment. Activities such as agriculture, fishing, hunting, mining and construction of buildings and infrastructure are almost inevitably connected with effects on nature, at the very least in the areas where they take place. Moving species from one ecosystem to the other (whether on purpose or by accident) can also have unintended and dramatic effects. Perhaps the fragility of nature is sometimes a little exaggerated, but it does seem as good thing to preserve wild biotopes as far as it is possible to combine with human life and technological development.

Ecological effects

It is in the nature of large-scale agriculture that it transforms the landscape and has a deep ecological impact on cultivated areas. Fertilizers and pesticides, especially if applied in large quantities and/or incorrectly, can certainly affect the ecology not only in the cultivated areas, but also in adjacent or even more or less distant areas.

The above is true also for agriculture with transgenic plants. Transgenic plants do usually not require less fertilizing (even if one can speculate in future commercialized transgenic plants with less need for fertilizers) but as outlined above they do in many cases require pesticides that are less or much less persistent in nature. Less persistent pesticides do not bioaccumulate in higher organisms to any significant extent before they are degraded, which must be regarded as an advantage from an ecological point of view.

However, it would appear as theoretically possible that crops designed to be toxic to insects or other vermin may have an ecological impact in the (limited, but still) areas surrounding the fields where these crops are being cultivated. For this reason, a large number of studies have been carried out in order to elucidate such potential effects.

Thanks to such a study, monarch butterfly caterpillars became world-famous as it was discovered that they suffered a higher mortality rate when forced to eat *Bt*-engineered (see above) maize in a laboratory. (For clarity, no negative effects on humans have been discovered.) The study was criticized, since it did allegedly not reflect realistic conditions. Still, the crop was withdrawn from the market and was replaced by a new one which in similar experiments was harmless to monarch butterfly caterpillars.

As stated above, all agriculture severely affects ecology in one way or another. It is therefore surprising that productivity per area unit is frequently completely overlooked. It should be very obvious that productivity and the area of cultivation are directly connected.

Modern agriculture produces significantly more food per area unit than traditional agriculture. To accept much lower productivity would immediately affect the size of fields and plantations. If, on the other hand, genetic and other improvements can allow for higher agricultural productivity the need for extensions of cultivated areas can be limited.

If it is considered as important to preserve wild biotopes, it should be considered as advantageous to aim for higher productivity. Genetically modified crops definitely have the potential to make a positive contribution in this context.

The containment issue

One of the aspects regarding transgenic plants, that the public is most concerned about, is the containment of modified organisms. Once a plant is planted on a field there is no guarantee that it will stay there. Quite the contrary, seeds and pollen are designed to spread and can do so over long distances.

In this discussion it is usually overlooked that genetically modified plants are already domesticated and have are not particularly viable outside the fields where they are cultivated. For instance, wheat is to a great extent overgrown and suffocated by other plants when it spreads into nature and the fact that it possesses one additional gene or gene cluster will not change that fact, especially if the gene encodes for a property that is irrelevant in the new environment. The anti-GMO lobby sometimes warns for "super-plants" that would have the potential to dominate entire biotopes, which is simply not a realistic scenario.

In nature, only organisms that are equally adapted or better adapted than other organisms can survive in the long run. While a transgenic plant containing a gene that allows for tolerance towards a specific chemical has a huge advantage in the presence of this compound it does not possess any advantage at all in nature (i.e. where the synthetic chemical is absent). Since it is a disadvantage for the organism to express a gene that it has no use for, selective pressure is rather likely to eliminate the gene in the long run.

A more relevant problem is that genes (allowing for tolerance to a pesticide) inserted into cultivated crops may spread to weeds through cross pollination. If the crop is closely related to naturally occurring weeds the weeds may acquire resistance to the pesticide and start invading the fields where the pesticide is applied.

Taking into account the attention that this problem has attracted it is remarkable that relatively few farmers have reported such problems. Anyway, the worst thing that could happen to the farmer would be that he would be forced to abandon the transgenic crop and return to the traditional form of cultivation. On any occasion, it is not a serious problem that weeds in nature are protected to individual chemicals, according to the discussion above. Weeds that in one way or another become tolerant to weed-killers are a very common problem also in traditional agriculture.

GM crops and the Third World

> "Anything that improves the taste, availability, and variety of produce for the US consumer should have an overall positive impact on the citizens of the world's health and wealth."
>
> David Evans of DNA Plant Technology in California, USA

Possibly, it is a little misfortunate that the GM industry and many scientists have focused so strongly on the third world when arguing in favor of genetically modified crops. Not that they are necessarily wrong, but this contributes to the strange perception that we should accept a new technology only if it is of direct and immediate importance to developing countries.

Inevitably, most genetically modified crops will cost money. It is expensive to develop new genetically improved plants and in the end the cost must be covered by the farmers who benefit from the improvements. And after all, third world countries have less hard currency to purchase this kind of products. This is of course not unique for genetically modified crops. It is likewise true for most modern technology, which first reaches rich countries and later penetrates other markets as patents expire and the production becomes cheaper.

That being said, genetically modified crops may indeed be important to the whole world in the future. It is for instance very likely that genetic improvements can yield crops that are more resistant to salinity and drought, which would make it possible to increase food production in areas with bad soils.

The "golden rice" is genetically improved rice, which produces several folds more beta-carotene than normal rice. Beta-carotene is converted to vitamin A by the human body and this product could therefore reduce or even eliminate vitamin A deficiency and childhood blindness in developing countries. The researchers behind the golden rice have made it available for free and it will possibly be used by some Asian countries in a few years.

The golden rice has been attacked by the anti GMO lobby many times – not for what it is, but for what it isn't. Indeed, the golden rice is not a "final solution to poverty and starvation." Certainly not, but it could reduce child blindness in many countries, which is at least more than many do-gooders have achieved. One technical application only very seldom revolutionizes the situation for ordinary people, but on the whole technology is fundamental for economic development, in both rich and poor countries.

Patent rights

Genetically modified crops can lead to financial gains by advancing agricultural production as well as the quality and quantity of food production. Also, there may be a long term economic benefit for farmers when growing modified crops that are designed to put less strain on the earth. This might for example be the case if the crops themselves can fix nitrogen from the atmosphere and thus not deplete the soil from this crucial substance.

The extensive research needed to produce modified plants can take years and may cost millions of dollars, whereas the cost of multiplying the plants once the proper genetic modifications have been made is very slight. Therefore, it is crucial to have patent rights for those companies that make the investments and take the risks that are involved in developing new genetically modified crops.

Usually, these patents expire after a number of years and the technology becomes common property, reducing the price of buying the seeds for genetically modified crops considerably. It is therefore important for the companies that have developed the technologies to recover the cost for research and development during the years when the patents are still valid.

The political context

> "The campaign of fear now waged against genetic modification is based largely on fantasy and a complete lack of respect for science and logic. In the balance it is clear that the real benefits of genetic modification far outweigh the hypothetical and sometimes contrived risks claimed by its detractors."
>
> Dr. Patrick Moore, chief scientist of Greenspirit Strategies and co-founder of Greenpeace, Biotech Bounty March 2004

The European Union is the world's largest importer of agricultural products and is the most important export market for US agricultural products. However, there has been a lack of enthusiasm in Europe for imports of genetically modified crops.

A plausible explanation is simply that genetically modified foods challenge traditional European ideas about food. From a scientific perspective it is easy to say that we should stop worrying and embrace genetically modified crops, as they are based on sound science and have many advantages.

But the problem we face is that people have powerful cultural attachments to food. Even though there is no evidence that anybody has gotten sick from eating GM foods, people are still sceptical towards genetically modified products, even in the US where many Americans have been eating genetically modified foods for many years.

People fear risks that they perceive as unknown and the scare tactics from environmental movements have played an important role in forming a mental picture of genetically modified crops as "Frankenfoods". The anti-GMO environmentalist lobbies, and the fear created in consumers, have affected EU policies. There are today stringent, time demanding and costly approval procedures for genetically modified corps before they can be sold to European consumers.

Europe is in danger of rejecting the new science of genetic modification of crops despite its benefits. It is important to communicate the message to European consumers that genetically modified crops are not mysterious, and alongside their economical benefits have potential in improving consumer health and reducing the strain of agriculture on nature.

In addition, lobby groups exploit the issue in order to prevent reforms of the Common Agriculture Policy. They are perfectly aware that many European farmers would have problems to compete on the world market without the subsidies of the CAP. It is in their economic interest to create the perception that Europe needs to defend itself from "foreign" food, since it contains genetically modified products.

Conclusions

Plant breeding through modern genetic methods is a technology that has many clear advantages to consumers, farmers, the food industry and nature. Hundreds of millions of people have consumed genetically modified products, and there is no substantial indication that this technology might be harmful to consumers. Indeed, from a theoretical perspective, there is no reason to assume that the consumption of genetically modified crops would be more risky than consumption of crops developed by traditional breeding methods.

The critiques of genetically modified crops that claim that the modified genes will spread in nature typically exaggerate the risks involved. The main effect of introduction of genetically modified crops in agriculture when it comes to biodiversity is that agricultural productivity is increased, so that human consumption requires less farmland and more land is allowed to grow naturally.

If the advantages of genetically modified crops are to be reaped by society, it is vital to have strong patent rights, so that development of beneficial technologies is rewarded. As important is that the regulations imposed on the industry are not so costly and time consuming as to hinder technological development and marketing of products.

It is also important to communicate scientific facts about genetically modified foods to consumers and politicians, debunking the myths spread by anti-GMO lobbyists and activists. It is not unethical or wrong to develop and market safe and beneficial products. Neither is it strange or unusual to use genetic technologies, as genes are constantly modified and passed on to other species in nature and in traditional breeding methods.