Genetic Engineering in Agriculture

Term Paper by

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1. Preface

We chose the topic “GeneticEngineering in Agriculture” because we considered it to be the most important and most interesting one for us concerning gene technology. The reason is thatgenetically modified food with herbal ingredients is nowadaysavailable in almost every country and gains more and more commercial relevance, especially on the American continent, is not yet clear. How genetically engineered products affect humans and animals is not known at all.
There is a big debate, which is dominated by two main groups. On the one hand there is the industry which brings genetically engineered products on the global market, reasoning that their products are better that naturally occurring ones (tastier, more stable etc.) and on the other hand there areenvironmental organisations which advert to the drastic aftermaths for our ecosystem. At the same time they accuse the industry of making profit out of this risky business and want to stop the growing of genetically engineered plants.
The aim of this study is it to find the advantages and the disadvantages of genetically engineeredfoodand their production process.

Our main questions are:

- Is the free planting of genetically engineered crops and vegetables dangerous for oureco-system?
- Is the biodiversity threatened?
- Is this global experiment damaging humans, animals and other living organisms?
- Is it the commercial relevance, which keeps these products interesting or do they really solve any problems in feeding the world’s population?

These questions will be discussed later on.

2.Introduction

2.1 Context

Over the past years genetic engineering has gained more and more importance especially in food production. Seeds are genetically modified to gain resistance against pests like insects, fungi, viruses and bacteria and are therefore an invention, which heavily influences the natural competition among living organisms. This intervention in the ecosystem has provoked many controversies because of unknown consequences for biodiversity and the environment itself.
Genetically engineered seeds (GE seeds) are not for free to use. They are patented and property of multinational companies and only usable for one crop.Therefore a farmer has to buy new seeds every year. After that you have to buy them anew. The world's biggest producer of GE seeds is Monsanto with a market share of 90%. Other companies are Syngenta, Novartis, Dupont, Bayer and some others. They advertise with slogans like: “GE seeds will bring you richer harvests!” or “GE products will solve the world's hunger problem!”. There are studies which show that there's no difference between the harvest of GE seeds and normal seeds. It's also a fact that there's basically enough food available for everyone on this world. It's just a problem of storage and distribution. The biggest share of GE crops isn't used as food for us humans but for animals. Only because

people in industrialized countries have such high demands for meat, people in third world countries don't have enough to eat although there would be enough.
Many people forget that cultivating GE (Genetically Engineered) plants on a field is not the same as growing them in a laboratory. If one releases them once, their control is no longer possible. It may be possible that a GE population will influence and spoil a “clean” population of the neighbourhood.
Besides all that, it's also widely unknown how GE products influence the human body and the environment. We just don't know yet whether they're dangerous for us or for animals and other plants. But since we're mixing all kinds of genes together there's a high chance of making mistakes.

2.2 Scientific History

Basically the NativeAmericans invented genetic engineering 8000 years ago by crossing the seeds of Teosinte (a group of large grasses including also corn). The advantages of such crosses were the much bigger grains on the plants.
But the first scientific discoveries in genetics were made 1865 when the Augustinian priest Gregor Johann Mendel presented his laws of inheritance by observing peas. He suggested that small pieces of information are inherited from one generation to the next.
FourYears later the Swiss physician Friedrich Miescher isolates DNA out of purulence. He calls it “nuclein”.
1902/03 Walter Stanborough Sutton assumes that the information Mendel was talking about was localized on the chromosomes.
1910 Thomas Hunt Morgan identifies several genes on chromosomes of drosophila flies. In the same year Hans Spemann clones a salamander by using the nucleus of an embryo.
1953 Francis Watson and Francois Crick described the structure of the DNA as double helix.
1970ties: Identification of restriction enzymes by Werner Arber and others.
1980ies: The first genetically modified plants are produced.
1995:The first product containing genetically modified ingredients come on the market.

2.3 Where and why is the Technique Used?

2.3.1 The Spreading of Genetically Modified Populations

Gene technologies are most often used to transfer genes into crops to make the receiver plant resistant against herbicides and pests, to force the receiving plant to produce some special proteins or vitamins (e.g. Vitamin A in “golden rice”) or just to intensify the flavour of e.g. a vegetable. The leading company in agricultural biotechnology is the US-American Monsanto which has about 90% of the global market share. Through Monsanto, genetically modified products were used by American farmers first and today the biggest density of genetically modified crop populations is in Northern America, followed by South America and Europe. Because of the idea to solve the problems concerning the feeding of the third world by supporting African and Asian peasants, transgenic plants have spread all over the world.

2.3.2 Possible Applications

The following list shows the practised gene transfers in agricultural biotechnology:

a) Herbicide resistance:
   A herbicide resistance means that the enzymes which would be attacked by a herbicide get immunized against the active ingredient of the herbicide.
b) Insect resistance:
   A resistance against insects can be reached through introduction of *Bacillus thuringiensis* (Bt) toxin in the plant. Bt-toxin is the most prominent insect pathogen that kills caterpillars.
c) Viral resistance:
   About 10% of the world's crop is annually destroyed by viral of fungal diseases. Plants can be modified by introducing antisense - RNA which makes the plant cell anti- viral.
d) N2-fixation
   The introduction of N2 producing genes (nif- genes) ->makes the plant independent of fertilizers.
e) Improvement of physiological properties
   Made to improve food quality.
f) Adaptation to environmental stress factors (e.g. heat, drought)
   Enables the plant to survive in difficult environments.

2.4 Alternative Treatments

The alternative to genetic engineering is an innovative, lastingagriculture whichuses our natural resources and considers nature.In the past years, several methods have been found to combat pests in an ecological way. One of this methods is for example the "push-pull" method, invented by biologists of mainly three institutes: The International Centre for Insect Physiology and Ecology (ICIPE), the Kenyan Agriculture Research Institute (KARI) and the Rothamsted Research Institute. The method has been invented because the European corn borer (*Ostrinianubilalis*) defeats a huge amount of the harvest in Eastern Africa year by year. Another problem is the parasitic plant *Striga*which lives from the sugar produced by the maize.
The basic idea is that the European corn borer gets pushed away from the maize and at the same time pulled towards a plant which is able to render him harmless. The „push factor" is the plant *Desmodium*whichis planted between maize plants and exudes an odor which dislodges the insect from the maize. The second advantage of *Desmodium*is that it secretes a substance that kills the seedlings of *Striga*. As „pull factor", Napier Grass (*Pennisetumpurpureum*) is planted as trap around the maize field because female Corn Borers like to put their eggs on the leaves of this plant. When the larvae eclose, they try to get into the caulis of the grass where they trigger the secretion of an adhesive substance and after a while they die of hunger.
This is of course not the only ecological method to combat pests but it is one of the most known and common. This example should just show that there are very reasonable alternatives to gene technologies which are much cheaper and therefore without any disadvantage.

3. The Genetic Engineering Techniques

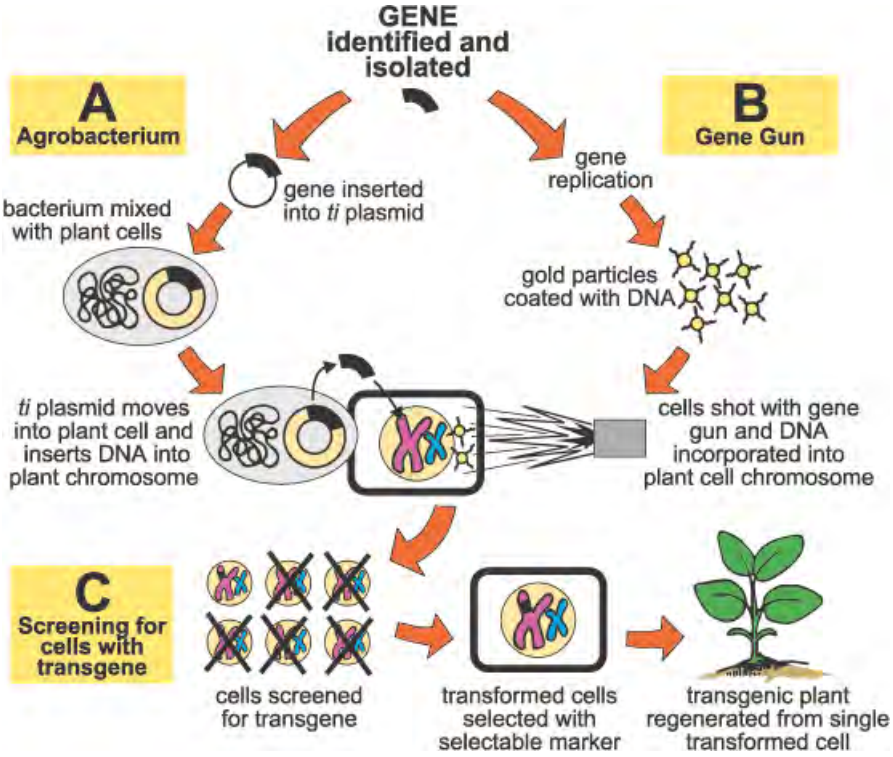
The idea behind transgenic plants is to improve their genetic setting, e.g. by making them resistant against viruses, fungi or insects or let them produce bigger, stronger, tastier fruits.
There exist various techniques for gene transfers into a plant, of which we'll present the most important ones later on.
The basic operation to put external DNA into a cell is always the following one:
-The DNA is isolated out of the donator organism and then fragmented by restriction enzymes (endonuclease).
-To get the donator DNA into the cell, a transport molecule called vector is needed. The vector consists of DNA which has to be extracted by using the same extraction technique as before.
-The enzyme ligase connects the vector and the DNA, which has to betransferred -> recombined DNA.
-The recombined DNA gets inserted into a cell of the receiver organism.
-Cells, which have accepted the recombinant DNA have to be selected and reproduced and grown into plants.

There are three commonly used techniques in genetic engineering for agriculture:

a) Transformation with a herbal vector
This method uses the soil-borne bacterium *Agrobacteriumtumefaciens* as a vector because it is able to integrate a special plasmid into the herbal DNA (which forces the plants to build tumours and to produce a nutritient called opine).
Genetic engineers have found out that it is possible to replace this plasmid by a smaller plasmid with included external genes, which have been put together by an E.coli bacterium before (so called binary vector system). Then, the target plants get contaminated with A. tumefaciens, the transgenetictissues get selected and in the end they grow in an "in-vitro" culture to adult plants.

b) Mechanical (“biolistic”) Transformation
A DNA- fragment is attached to a gold or wolfram particle, which is then 'shot' into the cell with a speed of more that 1'300 m/s. To do so, a gene gun is needed. This is an instrument developed in the late eighties and used now as a routine method for gene transfer. Since the particle shot into the cell is very small, cells and cell wall remain largely intact. One of the problems with this method is, however, that the integration of foreign DNA is not very stable.

c) Protoplast Transformation
This method allows a direct gene transfer. Plant cells are singled by enzymes (pekinases); then the cell walls partially digested with proteases. These results in so called protoplasts, which are kept together by only cell membranes.
The protoplasts are the either treated with polyethylene- glycol or with an electric shock. With both procedures, the membrane gets permeable and DNA can be introduced into the cell.



Picture: The basic process of plant transformation withAgrobacterium and the gene gun

4. Discussion

4.1 Discussion of Important Arguments

- Resistances

  This is the most common reason why plants are modified at all: to build up a self protection system against common pests and diseases. However, these resistances are not of sustained use since insects and bacteria will also build up resistances against the resistances which will make all the modifications useless.

- Bigger harvests

  This is the main advertising point for all the big gene companies and it's also one of the most controversial aspects. Maybe GE crops are better protected against damage but there are studies which show that they won't bring a bigger harvest. (→ see Resistances)

- Scientific progress

  There are huge amounts of money involved in the gene business (50 billion a year). A lot of this money goes into science and therefore huge progress is made there, which is also useful in other branches of GE.

- Possibility of creating new plants

  GE is like playing god. You create new species with custom features which you borrow from existing plants. This is very handy but also dangerous in terms of

keeping the ecosystem balanced and because you never know how foreign genes can affect the plant and its environment.

- Loss of biodiversity

If you supply a plant with all the protection against its natural enemies you're basically cultivating an unstoppable super plant with all the selective advantage against its competitors. Since you cannot control the spread of GE crops and their features your super plant will eliminate its competitors and you'll end up with nothing else than a genetically messed up cropple (crop + cripple).

- Private property of companies

GE seeds are private property of the companies, which developed them. They're not free to use which means that farmers have to purchase a license. They areunable to use the seeds for more than one year because the plants won't produce fertile seeds. This is very expensive for the farmer, especially in third world countries. They become fully dependent on the agro- company.

- Health hazards

The problem here is, that we don't know whether GE products are dangerous for our health or the health of animals. We'll probably find out in a couple of years.

- Environmental damage

In most of the GE crops there's a gen, which makes them resistant against persticides. This encourages the farmer to use them excessively since it cannot damage the wanted crops. It's clear that such pesticides shouldn't accumulate in big amounts in the soil or in the ground water; therefore, they should be used as little as possible.

4.2 Results

Surely, the use of gene technology in agriculture has advanced the research in this sector because there is a huge financial potential. Big companies as Monsanto or Syngenta invested and still invest a lot of money to ameliorate the techniques for genetic engineering and the process got standardized. The same companies pushed their own products with help of heavy advertisement and promoted their advantages over normal plants while not speaking about the dangers for nature.
Shortly; there is quite a big scientific progress made due to the application of gene technology in agriculture.
But how does it look for the process in solving the problems of feeding the world what these genetically engineered seeds basically were meant for?
The most important advantage promised by agricultural biotech corporations is a bigger harvest. With their techniques, plants with new, unique features (among others higher physiological value) can be grown and these features should make the crop growing more efficient and lucrative.
This promise is only kept over short periods of time because of several reasons. Firstly, the pests develop sooner or later resistances against the pesticides. A second problem is that unpredictable negative features of the transformed plants may show up because of the genetic intervention.

Today about 134 million hectares of arable land is planted with transgenic crops. About 9% of the total worldwide area and most of the products (about 90%) land in the animal feeding industry and finally in the shops as our food.

In Switzerland, farmers are not allowed to seed GE plants. There is a moratorium, which has been prolonged recently. First, research has to be carried out about potential effects of transgenic plants to the environment. Some field trials, however, are carried out under strict safety measures.
In general, Europeans are much more hesitant to eat agricultural products containing GE parts.
From an ethical perspective, we can see potential advantages, but the arguments against it weigh much more and we think that the 'green' gene technology is not the right way to go and that instead alternative biological methods to improve crops should be developed.

5. Summary

In this term paper we dealt with gene technology in agriculture and got to know the techniques for transferring genes from one to another cell and to grow transgenic plants. When we first thought about this topic we asked ourselves what we should think of the genetic engineering in agriculture. Is it a good thing, does it help to solve any problems?
We engaged with the advantages and the disadvantages of these products and our conclusion is that the cultivation of genetically modified crops is not reasonable when comparing the advantages with the dangers and all other disadvantages.

It was an interesting work and we realised that this important topic earned much more attention than it gets because this global experiment could seriously damage our nature and ourselves.

6. References

6.1 Internet

http://de.wikipedia.org/wiki/Gr%C3%BCne_Gentechnik
http://en.wikipedia.org/wiki/Transgenic_plant
http://www.greenpeace.ch/de/themen/landwirtschaft/gentechnik/gentech-landwirtschaft/
http://www.monsanto.com/
http://www.fao.org//docrep/006/y5160e/y5160e08.htm#P0_0

6.2 Literature

Biologie Oberstufe Gesamtband, Cornelsen
Gentechnologie: So oder so, Abschlussarbeit im Nachdiplomstudiengang in Umweltlehre, Universität Zürich

6.3 Reference

Margrit Leuthold, personal communication