Are Genetically Modified Crops our Future?

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The front page shows common wheat *(Triticum aestivum* L.*),* a strawberry *(Fragaria × ananassa)* and the typical double helix of the DNA. This paper deals with the possibility of changing the DNA of crops resulting in higher yields and the problems with this procedure.

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Reference: Dr. P. Ruggle

1. Preface

1.1 Motivation

When we first heard about our Biology-Paper, it did not take us too long to find an interesting topic. We had already talked about the significance of genetically modified (GM) crops and green gene technology as possible solutions for the world's food problems in Geography classes. Wheat, corn, rice or soybeans that are resistant to different diseases or parasites might revolutionise agriculture, especially in developing, fast growing countries such as India or Brazil. Even industrial nations such as the USA see the advantages of GM crops. In 2011 for example, 94% of soybean and 88% of US maize production was genetically modified. This sums up to a worldwide leading position of the USA. GM plants were produced on 69 million hectares in the USA.[i] This is caused by more efficiency and larger yields. The US policy supports the production; people in leading positions know about the growing problem.

"We need to double global food production until 2030" *[Ban KI Moon, Secretary-General of the United Nations, FAO summit, June 2008, Rome]*

GM organisms (GMO) might be the solution.

But there are also quite a lot of uncertainties since no one can exactly predict what will happen if you mix genes of different species. We wanted to learn more about the actual situation in Switzerland. We had already heard about some GM rape that had been found near Basel harbour.[ii] We thought that in general, any GMOs were prohibited in Switzerland. But they are not.

1.2 Our Questions

We want to focus on some studies that were performed as the national research programme NFP59 by the University of Zurich and the ETH Zurich and further research institutes throughout Switzerland from 2005 until 2013. Using these as examples, we will describe the controversial problems of GMOs. The ethnical question is frequently discussed in politics. We wanted to build an own opinion on GMOs and see whether the fear of GMOs in public is related to simple lack of knowledge or has a reasonable basis.

Our main interest was whether GM crops might be the future for Switzerland. Are GM crops always better and stronger than conventional seeds? And what happens if they are released to nature? Will they out-compete existing populations?

2. Introduction

2.1 Context

It was rather surprising to learn that for scientific research, neither lab experiments nor experimental releases to nature are forbidden and are actually performed. The national research programme NFP59 was introduced to study the effects of GMOs to the environment and how they behave in the field.[iii]

Two particularly interesting model organisms that were worked on are common wheat *(Triticum aestivum* L.*)* and strawberries *(Fragaria vesca* L., *F.* × *ananassa)*. Luckily, we were allowed to interview Prof. Dr. A. Erhardt who worked at the strawberry study at the University of Basel. It included observations on how the GM strawberries would interact with their natural relatives and whether hybridisation might occur and cause extinction for the unchanged forms.[iv] For the interview, see chapter 4.

These two series of studies are interesting, because they deal with exactly what we want to know.

Fig. 1: Common wheat *(Triticum aestivum* L.*)*

The scientists who worked with *F. vesca* focused on interbreeding with wild forms and environmental issues. The

Fig. 2: Powdery mildew *(Erysiphacea)* on leaves of common wheat *(Triticum aestivum* L.*)*

strawberries stand for many other wild plants that might come in contact with GM relatives. In their study, other scientists in Zurich looked at the effects of a gene transfer that makes the plant resistant to powdery mildew. Powdery mildew *(Erysiphacea)* is a fungus that causes up to 25% yield loss if it occurs in wheat fields. It is found on any kind of plants.[v] The model organism *T. aestivum* is one of the most important wheat species in worldwide production. This study looks at the effects a gene transfer might have on the organism itself. The main interest was to figure out how the GM wheat performs in the field. Do yields increase if we use GM wheat? We will describe what techniques were used to get the GM wheat. The applied technique, biolistic transformation is frequently used in biotechnology to modify organisms of each kind. Finally, we will discuss the results of the NFP59 and give our personal conclusion on this topic.

2.2 Scientific History

J. Sanford and T. Klein introduced the gene gun in 1987. The two plant physiologists invented it at Cornell University. It finally offered various new ways of transforming almost any plant species artificially. These have been improved during the last decades to form one of the most important means of transformation in gene technology.

"Advances in biotechnology have allowed the introduction of single genes against fungal pathogens into plants [1], [2]. The resulting transgenic plants offer convenient model systems for ecologists to study the effects of such single pathogen-resistance genes on other phenotypic traits of the plants and open up new horizons for gene × environment interaction studies [3]." *[O. Kalinina, S.L. Zeller, B. Schmid "Competitive Performance of Transgenic Wheat Resistant to Powdery Mildew" November 23, 2011, plos.org]* [vi]

An overall result of the NFP59 that has come to an end in 2013 is available on the programme's homepage.[vii] The researchers state that Switzerland does not need GM crops to assure food supply and satisfy economical interests.

2.3 Alternative treatments

Actually, there are several other possible ways of getting GM plants. Different vectors such as bacteria can be used for transfer. The cell wall can be broken down using enzymes or ligases. However, none of them is as effective as biolistic transformation using a gene gun for this particular application. Even though there are some unusable plants produced because the result is sometimes not as stable as wanted all in all it is reasonable to use this technique.

3. Engineering Technique

3.1 The Seeds

The seeds were taken from four different transgenic lines, two from Mexico (variety called "Bobwhite") and two from Switzerland (variety "Frisal"). All of them are *T. aestivum* L., which is a predominantly self-pollinating species. It is hexaploid, which means that it has 6 pairs of chromosomes of each kind (else than two like *Homo sapiens* does). Its growing season in Switzerland is from early spring until late summer.

3.2 Used Techniques

To get this type of genetically modified wheat, the original crops were treated with a gene gun. These devices can either look like an "ordinary" gun (industrial gene gun) or rather like any other lab device (stationary gene gun). Their name comes from the shooting of particles that is similar to shooting with a gun. This process allows putting a substance, in this case a specific gene, into a living cell's DNA.

Two types of gene guns are available. A so-called stationary gene gun is normally found in a lab. It is used for the first experiments until the expected results are achieved. After that the industrial gene gun is required. Because of its quite small size it is very handy. That is why it is used in the fields to insert the gene directly into the whole plant and not only into a test object.

Fig.3: A stationary gene gun

In this trial, the specific genes are placed into the stationary gene gun at the top in a holder. Underneath, a net is placed, which keeps the membrane with the genes on it. The last layer is made up from the living organism, in which the new gene gets inserted.

Because of the strong cell wall of plants, high pressure is required to bring the gene into the cell of the testing plant. Normally, little gold droplets are used to stick on the genes. In the end this package is shot with high-pressure trough the membrane into the core of the gene. The result is a genetically modified cell.

The industrial gene gun is in functionality very similar to the stationary one, they are only different in size and a bit in structure. While the big one aspirates the pressure by itself, the industrial one is linked to an air compressor. Otherwise it would not be strong enough to blast the genes trough the membrane. Also the distances between the different layers are shorter and the stopping screen is fixed into the aperture, but that does not influence the action.

Fig. 4: industrial gene gun

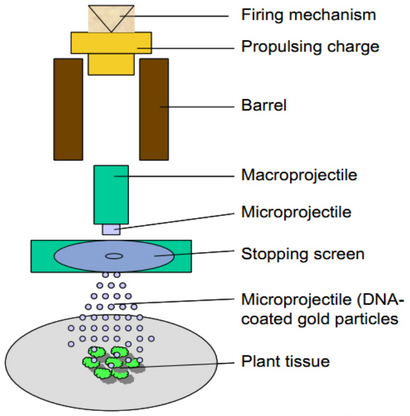

Fig. 5: biolistic transformation, schematical

4. Interview with Prof. Dr. Andreas Erhardt

R.Eggli: Dear Dr. Erhardt, we are very happy to have the opportunity of having this interview today. We would like to start with the national research programme NFP59 at University of Basel; you looked at GM strawberries and their interaction with their natural relatives[viii]. What were your most striking observations? Were the GM strawberries more competitive and would they interbreed with Swiss strawberries?

Fig. 6: Lab at the NLU Basel

Prof. Erhardt: Unfortunately, we were not able to perform as many experiments with GM strawberries as we would have liked, because we had problems with our Italian partner who produced the plants we needed for our experiments. At least, we could produce some hybrids between wild and GM strawberries. However, we did look at gene flow from cultivated (no GM) to wild strawberries. Since we did not find any gene flow, interbreeding is not expected even though it is basically possible. This is probably also caused by the fact that the cultivated strawberries are octoploid (8 sets of chromosomes) whereas our most abundant wild strawberries are diploid. However rare event might produce drastically changed plants, even though the probability is very low. Besides this, we found that

potential pollinators (bees) carry pollen from cultivated to wild strawberries more than 30 meters away from each other and may therefore act as pollen vectors for unwanted gene flow from GM to wild strawberries.

R.E.: If you had the choice to buy either GM strawberries or the conventional ones, which would you prefer? Why?

Prof. Erhardt: I would not be afraid of eating GM strawberries if they offered advantages compared to conventional ones such as a better taste. I regard the fear against consuming GM plants, which is widespread in the population, as exaggerated. Our digestive system has no problems with GM foods.

D.Kodatschenko: Let's look at this in a more general, global way. We know from Mexico, that GM maize can contaminate wild growing populations and occur in the production of a country far away from its original place of production.[ix] *Even in Basel, GM soybeans have been found.*[x] *Will, at one point in the future, all the crops produced on earth be contaminated with modified genetic materials?*

Prof. Erhardt: This is not likely to happen. The costs to produce GM crops are extremely high. To produce GM varieties of every cultivated species is not economical, at least at present. I expect the hype around GM crops to go back and in some reasonable cases we will use GM crops.

D.K.: How can one make sure that no interbreeding between conventional and GM plants occurs?

Prof. Erhardt: It is after my opinion not possible to completely prevent a contamination of conventional with GM crops, if GM plants are cultivated in close vicinity of conventional crops. One would have to create GM crops that are sterile, which is not realistic. The problem is that the public wants to know whether their food contains GM crops or not. Probably, we will have to introduce tests to analyse plants if we want to know that.

D.K.: Do GM crops affect biodiversity if they are cultivated without restrictions?

Prof. Erhardt: Yes, of course. New plants can always cause problems for our biodiversity. We surely have to carefully examine new GM varieties before they are allowed for cultivation.

R.E.: Let us change the topic. In public, gene technology is still a controversial topic. Most people would not want to end the current moratorium and allow production of both GM and GM free crops.[xi] *This shows how much they fear gene technology.*[xii] *Are those opinions and fears reasonable or restrictive?*

Prof. Erhardt: The problem is that most people have either a completely black or white view on gene technology, but transgenic crops vary greatly in their potential detrimental effects. Today's view is too restrictive. We need detailed experiments on the potential harm (e. g. unwanted gene flow to wild relatives) of the different GM crops.

R.E.: Nevertheless, transformations of DNA through selection using the mendelenian laws of inheritance have been performed for centuries. In the end, you always get a somehow changed plant. The most striking difference is the time needed for the process. Do they fear the technique rather than the result?

Fig. 7: Prof Dr. Andreas Erhardt

Prof. Erhardt: The fear has good reasons. There have been hard lessons to learn with DDT or other introductions of new products. But we need to get a more differentiated view on this topic. This can only be achieved, if people know more about gene technology. I think people are not even aware of the difference between technique and result. It is a fact that we would have a far more severe food (and health) problem if there was no gene technology.

D.K.: The NFP59 states in its overall results that today, green gene technology offers no significant advantages for Switzerland's agriculture but might in the future.[xiii] *Do you think Switzerland will become GM crops producer in the future?*

Prof. Erhardt: Yes, the moratorium will not survive in the longer run. There will be strict observations, regulations and restrictions on the use of different varieties, which is important since Switzerland is highly structured. We have much smaller fields than the US for example and hence the potential for contamination of conventional crops by GM crops or gene flow from GM crops to

wild relatives is high. However, my expectation is that the hype about GM crops will decrease and one will realise which GM crops are safe and which are not, and under which conditions it is safe to cultivate GM crops. This process may however take some time.
D.K.: If there was an election on that, what would you go for, moratorium or not?
Prof. Erhardt: I am ambivalent in that respect. A general moratorium is probably not the best way. We have to discuss every single GM variety and decide whether it is safe and suitable for Swiss agriculture or not. We would need a group of experts that would make the final decisions.
D.K.: Dr Erhardt, we want to thank you for those interesting insights to your work.

5. Discussion

5.1 Results of the NFP59

The NFP59 states in its results that GM crops are probably not supposed to be our future. At least, they will not be our main food within the coming decades. The scientists who worked with wheat showed that genetic modification of organisms is still a tricky business. One of their observations was that, probably due to the changes in the DNA, wheat showed unnatural growth.
„Three of them showed reduced fertility, four lines had chlorotic leaves, and two of them a strongly reduced plant height and a slower development“.*[B. Keller, S. Brunner "Analysis of Pm3 resistance gene function in transgenic wheat" University of Zurich[xiv]]*
Phenomena like this are called „pleiotropic effect".[xv] The malformations only occurred in the fields, not in the lab. They led to a decrease in the yields. Even though the loss due to powdery mildew was reduced, less wheat was produced than on reference fields using conventional crops. This shows impressively how uncertain we are about the effects of gene manipulation. In the future, we will have to perform more experiments on this field to sort out all the issues connected with the technology. On this respect, the overall results are coherent with the opinion of Prof. Dr. A. Erhardt.

5.2 Ethical Aspects

The use of GMOs in agriculture is controversial but certainly avoidable. As seen in the studies, we do not yet know enough about the organisms we produce to sort out every possible source of problems. The advantages are not necessarily strong enough to balance the reasonable fears in public. The costs for the production of every new product can reach a dramatic scale. Eventually, the biotechnology companies are the only real winners if they can sell a certain GMO. If Switzerland would agree on cultivating GM crops, the government as well as the farmers could become more and more dependent on a few companies whose mayor aim is profit.
Scientific progress is important. There are several unproblematic plants that have been modified and do not cause any harm. If a GMO has no close wild relatives and does not outcompete existing populations, no rational arguments speak against a controlled cultivation and use of it. Finally, everybody has to decide for himself or herself whether he or she wants to consume GMOs or not.

6. Summary

In our paper we gave an overview on the controversial subject of GM crops in agriculture. We explained one of the most important transformation methods in green biotechnology and gave the specific example of the national research programme NFP59. The interview with Prof. Dr. A. Erhardt offered us a great opportunity to dive into the matter and experience the research of a specialist in this field. We were able to see the topic from a new perspective. We both share the opinion of Prof. Erhardt. There is still a lot research to be done. Finally, knowledge seems to sort out most of the fear. If gene technology offers advantages, which it does, we will and may use it in the future.
The whole process of writing this paper took us a long time but we are pleased with the result. We want to thank our families for the support and Prof. Dr. A. Erhardt for his time and help. We also thank Dr. P. Ruggle who answered all our questions.

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