



Earth on fire

climate change from a philosophical and ethical perspective

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Case 2 ■ Genetically modified organisms

GMOs: A solution to changed climate conditions

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Can the genetic modification (GM) of crop plants help to solve some of the problems we will be facing due to climate change? In my opinion the answer is clearly yes. Genetic modification offers a range of opportunities which ordinary plant breeding does not, and with the problems that we are facing, it would be inexcusable not to use this technology. In the ongoing debate on climate change and food production, one of the arguments voiced more and more often is also that the development of new crops using GM technologies will be critical to meeting future challenges. Here, I will try to shed light on which problems the predicted climate change will cause as well as the other challenges which global food production is facing. This will be compared to what we know about genetic modification and its potential today.

Plant breeding is as old as agriculture. We can imagine that the Stone Age farmer while cultivating his land with the first crops occasionally came across a variant with larger, and maybe even better-tasting, seeds or tubers. He would then store some of these variants as seed grain for the next year. In this way, our crops have been improved – or bred – into what we know today. In some cases, the breeding is so comprehensive that we do not fully know where the plants came from. Within the past century, this breeding process has become much more focused. Variants with useful properties have been cross-bred, and in other cases new variants have been created through irradiation or treatment with chemicals that change the properties of the plant genes. The main limiting factor in traditional breeding is, however, that only closely related species can be cross-bred, thus considerably limiting which properties can be combined. Besides, irradiation/chemical treatment affects the plant genes at random, and most new variants are inferior to the parent species.

Genetic modification does not have these limitations. In reality, you can transfer any gene from any organism, and you can predict which property the gene will give the plant. This is, of course, why the expectations for this technology are so great. Box 1 briefly describes the terminology and techniques used today for the genetic modification of plants.

Population growth

Global plant production has previously faced major challenges in terms of ensuring adequate food supplies. So far, it has succeeded in keeping pace with the population growth through the development of new plant varieties by means of plant breeding as well as improved cultivation methods such as the use of irrigation, fertilisation and pesticides. In the developing countries, particularly in Asia, this development is called the ‘Green Revolution’, where the 1960s and 1970s saw a doubling in the yields of main crops like rice and wheat. Approx. 50 per cent of the productivity increases are ascribed to varieties with shorter growing periods and more compact growth, better nitrogen utilization, improved disease resistance and adaptation to different climate conditions. A good description of the Green Revolution can be found in *Wikipedia*.

We are now facing far bigger challenges. In 2050, the Earth’s population will total nine billion people, livestock production is expected to see a sharp increase due to strong economic growth in a number of developing countries, and an ever larger share of plant production, especially corn, is used for bio-ethanol. Combined with poor harvests in a number of countries, very limited stocks as well as historically high oil prices, these factors led to dramatic increases in food prices in 2007–2008 (von Braun, 2008). At the same time, the industrialised countries in particular have expressed a desire for larger areas of undisturbed countryside and reduced environmental impacts from nutrients and pesticides used in agriculture. Energy and grain prices fell again during 2008, but the big question is whether the days of low energy and food prices will not become a thing of the past.

To illustrate the scope of the problem, I have chosen to briefly refer to the FAO report ‘World Agriculture: towards 2015–2030’, which was published in 2003.

Definition: Genetic modification

Box 1

The terms ‘genetic engineering’ and ‘gene splicing’ are used synonymously with ‘genetic modification’ and ‘genetic manipulation’, and genetically engineered organisms are called ‘GMOs’. The term ‘gene splicing’ comes from the fact that you can cut and paste genes and gene sequences, using different enzymes, into new combinations which are subsequently inserted into another organism. The actual insertion is often referred to as ‘genetic transformation’.

The first genetically engineered plants were made in 1983. Two methods are primarily used today: a method whereby the genes are injected into the plant tissue using a so-called gene gun or by means of a soil bacterium (*Agrobacterium*) which is capable of transferring genetic material to plant cells. Techniques have gradually been developed for genetically engineering all our cultivated plants.

This means that it was published before the full brunt of the food and energy crisis was felt, but it provides a detailed assessment of the challenges which the global agricultural sector is facing: Producing food for eight billion people by 2030, without taking into account climate change, biofuels and increasing energy prices. The FAO emphasises that they are not presenting a strategy but a projection and an assessment of how global agriculture will develop to meet the increasing demands on food production.

According to the report, annual grain production is expected to increase from the current 2 billion tonnes to 3 billion tonnes by 2030, of which approx. 60 per cent will be used as feed. The developing countries will increase their imports of grain from 110 to 265 million tonnes by 2030. The FAO expects that plant production will increase by 67 per cent from the start of the millennium and up until 2030. In the developing countries, the use of irrigation will increase from about 40 per cent to 50 per cent of the agricultural production, resulting in a 14 per cent increase in water consumption. In some areas, this does not pose a problem, whereas other areas, e.g. North Africa and the Middle East, already have a negative water balance, i.e. consumption is higher than the water supplied. The use of fertilisers is expected to see an increase from 138 million tonnes at the start of the millennium to 188 million tonnes by 2030. Approx. 120 million hectares of new farmland are expected to be added (an increase of 13 per cent in the total agricultural area), primarily in South America. According to the FAO, 1.8 billion hectares in the developing countries can potentially be used for cultivating plants of some kind with acceptable minimum yields. Ninety per cent of this area is located in Latin America and sub-Saharan Africa. The FAO report laconically states that some people believe that mankind has already cultivated too many areas at the expense of the natural world, while others are of the opinion that there are large areas which should be included for agricultural purposes.

Overall, the recipe is thus an increased use of existing methods: intensive farming and greater use of irrigation and fertilisers. To strike a balance, major productivity increases are required, primarily in the developing countries. Many people thus believe that we need a new Green Revolution – a Biorevolution – which both ensures higher productivity and, at the same time, less environmental impact.

Climate change

The comedian and actor Peter Sellers has been quoted as saying that the problem with predicting the future is that it is like scratching yourself before you start to itch. As for climate change, the itch seems to be well-defined, even though the extent is still uncertain. As for plant production, the latest report from the UN's Intergovernmental Panel on Climate Change (IPCC) from 2007 projects that, in addition to getting warmer, the climate will also become less stable. Major agricultural areas, in particular the large river deltas in Asia, will be threatened by the rising sea levels. It is predicted that the temperature

increases will result in higher plant productivity in upland areas, while low-lying areas will see a decrease, particularly in tropical and subtropical regions. Globally, higher productivity is expected at temperature increases of up to 3 °C, while higher temperature increases will result in lower productivity.

The speed of the climate change will be a very important factor. Slow changes will allow plant breeders and producers to gradually adjust plant production to the new growing conditions where existing varieties from other climate areas can be introduced and new varieties can be developed. Climate stability will be another important parameter. Higher and more fluctuating temperatures and precipitation will stress the plants and result in lower yields. The environmental impact is also expected to change, taking the form of new plant diseases and pests. These effects are currently being assessed worldwide in experiments and by designing models, and a complex picture is painted for the various combinations of crops and diseases/pests with both positive and negative effects on crop productivity and yields.

A third parameter of major importance is the atmospheric content of carbon dioxide (CO₂). CO₂ is the raw material for the photosynthesis of plants, and it is well-documented that for most plants higher CO₂ levels will lead to higher productivity and yields. A doubling of CO₂ levels will thus increase yields by 10-25 per cent. At higher CO₂ concentrations, plants will also consume less water as the leaves' stomata can remain closed for a longer period as there is sufficient CO₂. Some researchers actually believe that the most frequent type of photosynthesis, the so-called C₃, was developed for an atmosphere with considerably higher CO₂ levels than those seen today. There is, however, a downside to higher productivity. The increase will primarily be in the form of carbohydrates, while the content of minerals, some vitamins and proteins will be relatively lower. This will affect the quality of the products, for example the baking quality of wheat, and result in lower nutritional values, a problem which will in particular affect poor populations in the developing countries whose basic diet consists of wheat, rice, corn, cassava and potatoes (Easterling et al., 2007).

How are we then prepared for a Biorevolution? Our understanding of the genetic basis for the properties of our crop plants is rapidly developing. Today, we know the complete structure – sequence – of all genes in rice, corn and alfalfa, and for barley and wheat steps have been taken to sequence parts of these plants' chromosomes. A complete sequence is also available for a number of so-called model plants, i.e. plants that are simple to use in experiments. It is now possible to test how thousands of plant genes respond to external factors such as drought, cold, salt stress and disease attacks and which genetic mechanisms determine the plant's constituents and development, including flowering, fructification and seed production. At the same time, today's very detailed genetic tools can quickly generate detailed genetic maps and identify so-called genetic markers for a number of properties.

This knowledge provides us with a number of opportunities to improve plant properties. In some cases, it will be possible to introduce these properties from wild relatives by cross-breeding or by inducing changes of the genes' properties by irradiation or chemical treatment. In other cases, genetic engineering will be required. Different researchers can have different preferences regarding their choice of technology. I personally believe that genetic modification provides us with far more opportunities and a much quicker and more efficient breeding process than cross-breeding and mutagenesis.

Growing genetically engineered plants is today well-established in all parts of the world with the exception of Europe where only Spain uses a significant proportion of its agricultural area (approx. 50,000 hectares) for growing genetically modified corn (James, 2007). In 2007, 114 million hectares were used for cultivating GM crops globally, an increase of 12 per cent on 2006. The crops were cultivated in 23 countries by more than ten million farmers, 90 per cent of whom live in developing countries. The crops include almost exclusively herbicide-resistant (HR) soya, insect-resistant (IR) and/or HR corn and cotton as well as HR rape. In addition, smaller areas are used for cultivating virus-resistant papaya and HR squash. The insect resistance is based on the production of the so-called Bt toxin in the above-ground parts of the plant or in the roots, and the herbicide resistance is against glyphosate (Roundup) or glufosinate (Basta), the glyphosate resistance being the dominant technology. A significant increase is being seen in the number of corn and cotton varieties with both insect and herbicide resistance.

According to Brookes and Barfoot (2006), GM crops have increased the net income of GM growers by USD 27 billion in the 1996-2005 period (USD 5 billion in 2005). Their calculations also show that the introduction of HR and IR crops over a ten-year period has led to a reduction in the pesticide consumption of 224,000 tonnes of active substance as well as a 15 per cent reduction in the so-called *Environmental Impact Quotient* (EIQ), which is calculated on the basis of the amount of active substance used, the toxicity and degradation rate of the pesticide as well as discharge to the surroundings. In a climate context, it is very interesting to note that the cultivation of GM crops has resulted in a reduction of CO₂ emissions of around 1 million tonnes due to less driving in the fields. HR crops make it possible to dispense with soil preparation altogether, which has resulted in the binding of an additional 8 million tonnes of CO₂ in the ground. The implementation of particularly Bt cotton has reduced insecticide spraying considerably, especially in the developing countries, with measurable positive health effects for farm workers.

We thus have a technology at our disposal which in a very short time has had a significant impact on global plant production and benefited both the economy and the environment. So far, only four species have the HR and/or IR resistance properties. A large number of other plant species with other properties have been subjected to field tests, but so far only those mentioned above have proved commercially viable. Today, new genetically engineered varieties are developed in the private sector by multinationals (with China and India as



The discussion on the use of gene technology in food production has been characterised by considerable public scepticism about the technology. Here, a group of Spanish demonstrators are protesting against genetically modified plants at a conference for plant biotechnologists held on Tenerife in 2007. (Photo: Preben Bach Holm)

potential exceptions). It is thus difficult to predict which new crops are in the pipeline for commercialisation, but according to the companies, their main focus is on crops with better nutritional properties and varieties with high drought tolerance (Monsanto, 2008).

So how can we use genetic modification of our cultivated plants today as a tool for adapting to future climate change? We have come far in terms of technology and knowledge, but far more comprehensive and focused research and development initiatives are required to handle the necessary complex changes. In this context, the public sector must play a much larger role to promote the development of new varieties based on the long-term needs of society and not leave the technology to a small handful of breeding companies which, for obvious reasons, have to focus on earnings and their short-term bottom line. The EU area needs, in particular, a much speedier approvals procedure for genetically modified plants as the existing regulations are very comprehensive and make it a very slow and costly process for applicants wanting to market new varieties. It goes without saying that new genetically modified varieties should be subjected to a risk assessment, but as the extremely comprehensive risk assessments still have not revealed any significant problems regarding the health and environmental effects of genetically modified plants, the caution exercised today seems to overshoot the mark (Sanvido et al., 2006 and European Food Safety Agency, 2008).

The debate over the past ten years has shown that for some people genetically modified plants pose a number of ethical and attitudinal dilemmas where genetic modification is seen as part of undesirable industrialised agriculture where the natural world is manipulated. Others conclude that there is no need to take any risk, irrespective of how hypothetical it may be, with these crops if there are no benefits. A lot suggests that the latter group, which probably includes most citizens, is starting to take a more positive view in light of the future scenarios involving climate change and increasing food and energy prices. In this discussion, it is crucial that the population is given a free choice and that you respect that there are different opinions on future plant production and solution models. This choice is not possible without information on the pros and cons based on facts and science.

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Case 2 ■ Genetically modified organisms

GMOs: The right way of taking responsibility?

RIKKE BAGGER JØRGENSEN

Global climate change is caused by the industrialised countries' energy consumption and pollution, but it is the developing countries that will face by far the biggest problems with the future climate (IPCC, 2007). The developing countries are where extreme climate events and natural disasters will most frequently occur, where the cultivated area will be reduced most owing to higher temperatures and where biodiversity will be most threatened due to increased deforestation and the invasion of new species (Abate et al., 2008 and IPCC, 2007). We, in the rich part of the world, are the environmental sinners and the developing countries are the victims, so we thus have a major responsibility to fight hunger and increase the living standards in the poor parts of the world. We can do so by contributing to fair, environmentally correct and socially sustainable development in the developing countries. If we do not take action on this injustice here and now, the result will be increased political tension between the developing countries and the developed world.

How do we prevent food shortages when agricultural production is under pressure due to extreme climatic conditions? Are genetically modified organisms (GMOs) adapted to the changed environment the solution to the problems of global hunger? Promoting GMOs as a panacea to the challenges which global food production is facing has not lacked backing. In the industrialised world, both Danish politicians and opinion-makers (e.g. the Danish Minister for Food, Agriculture and Fisheries Eva Kjer Hansen), international politicians (former US President George Bush) and the agrochemical industry (Monsanto, 2008) have been advocating the message that GMOs should save future agricultural production.

Multinational biotech companies have accelerated their production of GMOs

But are GMOs the answer to the challenges resulting from climate change? Today, it is possible to produce genetically modified, climate-tolerant crops which can resist drought and high temperatures and which can grow on land with a high salt content (Hitesh et al., 2007). Intensive research is being

conducted in this area, and major agrochemical companies such as BASF, Syngenta and Monsanto have apparently already started patenting genes which make plants tolerant to environmental stress. Several hundred patent applications have been submitted to cover the use of climate-related gene families. Spokespersons for the agrochemical companies state that it is necessary to patent the genes to effectively meet the world's hunger problems (*Washington Post*, 2008). So are these companies on a philanthropic mission with the purpose of feeding hungry people in the developing countries? There is no doubt that the large agrochemical companies would like to sell their stress-tolerant varieties to Africa, South America and Asia, because, as we know, genetically modified varieties cannot be sold to the Europeans who are frightened of GMOs! According to Eurobarometer, approx. 75 per cent of European consumers are negative towards GMO technology, and the food crisis has not altered this picture much; for example, in France and the UK the opposition is actually growing (Block, 2008).

Locally adapted varieties are flexible to climate change

If genetically modified varieties of the cultivated plants are part of the solution to the food crisis in the developing countries, the GM varieties should be developed from locally adapted plant material (Cohen, 2005). The local genotypes have been selected over centuries and are thus particularly well adapted to the local environment. The majority of these will be far more genetically diverse than the modern varieties which we can supply. This diversity serves as a buffer against local stress factors, and the diversity cannot be replaced by a limited number of inserted GM traits (transgenes), coding for, e.g., drought, salt and temperature tolerance. The local needs are thus best met through public research and development of crops from local material and in local conditions. This means that the patented genes must be made available free of charge or at a low cost to countries which want to produce their own GM crops, so that the genes can be inserted or crossed into locally adapted material.

Dare we believe that the multinational patent holders will make the genes available free of charge? This means that the patent holders will also have to waive their patent rights to farm-saved seeds. Taking out seed from the harvest as seed for the next crop is common practice for farmers, especially in developing countries. The Monsanto vs. Percy Schmeiser case shows that farm-saved seed is not accepted in industrialised countries. In the light of this case, it is difficult to imagine that companies like Monsanto would allow farm-saved seed in the potentially large markets in Africa, South America and Asia as this would undermine their market potential.

Do GM varieties give better yields for developing countries?

Conventional types of biotechnology like Marker-Assisted Selection (MAS) in breeding, in vitro culture, fermentation etc. are widely accepted and used in developing countries and have increased the yields for many crops (Abate,

Monsanto vs Schmeiser**Box 1**

In 1998, Monsanto filed a lawsuit against Percy Schmeiser, a farmer from Saskatchewan in Canada, because the company believed that he had deliberately taken seeds from their GM Roundup-resistant variety for seeding his field the following year. As the genes inserted into the GM varieties are patented, you waive your right to use farm-saved seed when you buy a batch of seeds from a GM variety. However, Percy Schmeiser claimed that the GM seeds were dispersed by wind to his field from neighbouring fields and that he was thus entitled to harvest the plants sprouting from the seed and use them for seeding; he was, after all, under no obligations to Monsanto.

Schmeiser became an international symbol for the groups and movements working against GMOs in food production. The public debate focused to a large extent on the problems related to GM plants from neighbouring fields polluting non-genetically modified crops. The Canadian Supreme Court did not deal with this issue, but in 2004 found Schmeiser guilty of deliberately infringing Monsanto's patent rights by collecting seeds from the genetically modified plants. The court decided, however, at the same time that Schmeiser should not pay any damages to Monsanto as it could not be proved that he had made any extra profit by using Monsanto's plants.



Percy Schmeiser. In an out-of-court settlement, Schmeiser settled his lawsuit with Monsanto in 2008 as Monsanto agreed to pay all clean-up costs of removing GM plants from Schmeiser's field.

2008). Whether GM crops result in increased yields is, however, far from certain. Data show, for example, that the yields for some GM crops in a given year may be 10-33 per cent higher in one location and lower in other locations (Abate,

2008). Figures from the *International Service for the Acquisition of Agri-biotech Applications* show that it is mainly the growing of Bt cotton in China and India and the growing of herbicide-resistant soya beans in South America which have been successful (Brookes & Barfoot, 2006) – it is profitable business to cut down the rainforest to grow GM soya beans for bioethanol, which, among other things, is exported to the USA and Europe. The low yields for many GM crops are, among other things, due to the very limited selection of GM crop varieties. The poor variety selection is blamed on patent rights, know-how and the high production costs for a new GM variety. Only the large multinational biotech companies have the patents, knowledge and financial resources required to develop the varieties and have them approved, and they have no direct interest in producing several different varieties. The developing countries which choose to cultivate the West's highly bred GM varieties will typically cultivate them under low-input conditions, which will often result in low yields: "You get fantastic yields if you are able to apply fertilizer and water at the right times and herbicides to go along with that. Unfortunately most African farmers cannot afford these inputs" (N. Zerbe, 2004).

Risk assessment and legislation – developing countries lagging behind

Even though most GM crops produced in developed countries have been subjected to thorough risk assessment, this risk assessment will probably have to be repeated if the crop is to be cultivated elsewhere in a different environment. Interactions between the GM crop and ecosystems with totally different organisms imply that new scenarios have to be evaluated. Legislation is in place in both the USA and the EU which prescribes how the risk assessment should be performed (see, e.g., EU directive 2001/18/EC). In many developing countries, such regulation is, however, not yet in place (Nelkin et al., 1999). Without a scientifically based risk assessment and a regulated approvals procedure, ensuring environmentally secure cultivation will be a problem (Cohen, 2005). Thus, we have a moral obligation to contribute to providing the developing countries with the know-how required to guarantee a sensible assessment of the GM crops. For GM crops cultivated in areas where non-GM crops are also cultivated, it is important to establish co-existence legislation to prevent GM and non-GM crops from being mixed which will entail quality and financial risks – or maybe even lawsuits, like the Schmeiser case, from biotech companies if genes are spread naturally in the surroundings. GM cultivation may potentially undermine local cultivation strategies which ensure food safety and economic sustainability.

GMO food aid to Africa – politics as a co-player

The US offer of food aid to southern Africa in 2002 is one example of how the West's exports of GM varieties to developing countries are not just an unproblematic helping hand. Noah Zerbe, Professor at Humbolt State University,

has reviewed the details of the food offer, and he believes there is reason to conclude that famine relief in southern Africa was not the real purpose of the generous US offer (Zerbe, 2004). The primary reason for the offer was to promote GM crops, increase their market distribution and, at the same time, ensure multinational agrochemical companies' control of the market and last, but not least, to outmanoeuvre and isolate GMO-sceptical Europe. Southern Africa rejected the US food offer despite the imminent famine. According to Zerbe, the reason for this was not so much environmental and health concerns in connection with the GM crops but rather a question of the domestic and international political economy, in particular a fear of being excluded from the European market and the potential opportunity of obtaining an extra high price for crops certified as non-GM crops.

If developing countries reject the West's generous offers of GM crops, it may also be related to the history of the developing countries. Many developing countries are former colonies, and the resulting dependence on multinational agrochemical companies is too reminiscent of colonial times and may make it difficult to accept the varieties.

If GMOs are not the solution to the climate crisis, what is?

There are many reasons why GM crops are not the solution to the developing countries' climate problems. To name but a few:

- Patented transgenes and the associated limitations in breeding and cultivation strategies
- Lack of locally adapted varieties for low-input farming
- Lack of both technology and technology assessment know-how (risk assessment and co-existence rules)

The main reasons for the food crisis affecting the developing countries today are the lack of investment in their agricultural sectors over the past 30 years and an unequal distribution of the world's food due to trade restrictions (Abate, 2008). What the developing countries need are investments which can stimulate the production of high-value crops and crops with unexploited potential, trade barriers between developing and developed countries must be removed, the local markets with their multifunctional activities must be stimulated, and the local communities must be assured a guaranteed food supply and quality. Forget all the talk about GM crops being the only hope – focusing on GM crops deflects the attention from the larger picture and the fact that it is first and foremost the more basic and conventional areas of the developing countries' agricultural sectors which need resources. You cannot rule out that GM crops in some cases may be the solution to specific cultivation problems, but GM crops are and will only be one of many small elements in the solution which will prepare the developing countries for the future climate change.

GM crops and the developed world

But global climate change will also affect the developed countries. So will GMOs play a role in our farming? Not that we will suffer much from climate change – on the contrary actually. The thing is that the higher temperatures will most likely increase agricultural production in at least northern Europe (IPCC, 2007). The argument for using GMOs here in Scandinavia has also been that we must produce more so we can export food to countries which cannot feed themselves. But the fact that we must profit from their hunger clearly does not help solve the problems in the developing countries. The developing countries will become even more dependent on imported food than is the case today, and unless they have other products which we demand, their economies will come under even more pressure.

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Case 2 ■ Genetically modified organisms

Study questions

- 1 According to the two authors, which role can GMOs play in connection with the changes in food production which appear to be caused by climate change?
- 2 On which arguments do they base their assumptions?
- 3 How do the two authors assess the risk of developing and using GMOs?
- 4 How do the two authors regard public scepticism about GMOs and the significance of this scepticism for future development?
- 5 Which ethical problems do the two authors highlight in connection with GMOs?
- 6 Discuss whether the two authors' disagreement is primarily due to different interpretations of the natural scientific knowledge in the area or to different values?