Feeding a growing world: Case studies of genetic modification

Student activity sheet

Introduction

Genetic modification, and in particular GM food, remain controversial, despite some obvious benefits. Some of the opposition to GM food may be due to fear, while other objections may be better founded. GM crops have been grown for more than 20 years in some areas of the world, so we now have data to evaluate. GM crops are not grown in the UK (except for research), but many animals are fed on feed that contains imported GM soya, and some GM food for humans is imported and sold here too.

A number of case studies are provided below. Take notes of the benefits and risks of using GM crops that are revealed by these case studies, and use these to inform you as you prepare a survey or a debate.

Case studies

Soya beans

Dusan Kostic / Fotolia.com

Figure 1 Soya bean plants.

Genetically modified soya bean plants resistant to the herbicide glyphosate ('Roundup®') were produced so that weeds competing with the 'Roundup Ready®' soya plants could be killed with the herbicide. This is an example of a first-generation GM plant, in which the main advantage appeared to be to the company producing the herbicide. The American Soybean Association, however, states that growing glyphosate-resistant soya bean plants protects the environment because herbicide application is in fact reduced and tillage practices (used to control weeds) are changed.

Possible risks include the potential for the gene for herbicide resistance to pass into weeds, producing 'superweeds', or for increased use of herbicide to increase the selection pressure on weeds, encouraging the development of herbicide resistance. The more farmers rely on glyphosate, rather than rotating different herbicides or using other weed-control methods, the more this problem is compounded, leaving the resistant weeds to spread unchecked. However, this does not appear to have created serious problems so far.

Another risk is to the wider ecosystem. The rapid decline of the monarch butterfly population in North America, for example, may be partly due to climate change and logging, but the major cause seems to be the elimination of milkweed, the breeding habitat for monarch butterflies and food for their caterpillars, by herbicides used on GM soya and maize.

Golden Rice™

Courtesy Golden Rice Humanitarian Board

Figure 2 Normal rice (left) and Golden Rice™ (right).

Each year, about 500 000 children in India go blind through lack of beta-carotene, the precursor to vitamin A. India is not alone; many countries, including the Philippines and Vietnam, suffer the effects of vitamin A deficiency, resulting in blindness, fatigue and even death. Golden Rice™ was genetically modified to contain a gene from daffodils that codes for beta-carotene, so that this would be present in the rice grains. As the people suffering from lack of beta-carotene live in areas where rice is the staple food, and other plants containing beta-carotene are inaccessible to them, this seemed a great solution to a problem, particularly as this rice would cost consumers no more than unmodified rice. Golden Rice™ could also help to reduce economic losses caused by the ill health and premature deaths of the population.

Some people feared that farmers would have to buy the modified seed every year, but the company that developed this rice has offered free licences to farmers so they can keep and replant rice seeds without paying a licence fee.

Concerns that people might react badly to the presence of the beta-carotene in rice led to extensive trials of this product. The original strain of Golden Rice™ was found to not contain enough vitamin A to combat the deficiency in most of the population. A later strain has been created, containing more beta-carotene. Beta-carotene is, however, found in many foods, and some people argue that the best way to combat malnutrition is to encourage local populations to plant a variety of fruits and vegetables in any space they have in order to eat a balanced diet, rather than relying on Golden Rice™ as a single food staple for their essential nutrients.

Africa Harvest

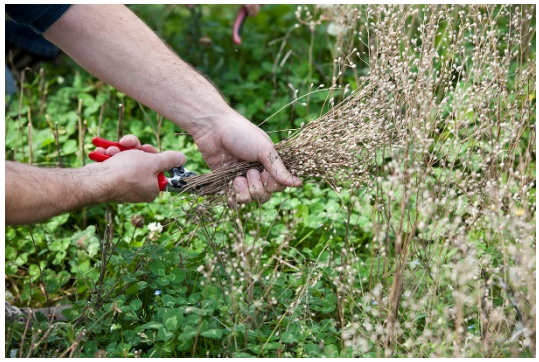
A biotechnology company in Kenya, Africa Harvest, led by Dr Florence Wambugu and with backing from Monsanto and the Rockefeller Foundation, is producing plantains that are nutritionally enhanced to contain more zinc. In areas where people eat very little meat, the diet may be deficient in zinc, an important enzyme cofactor and essential for regulating insulin secretion. Zinc is also important in gene regulation via certain transcription factors called zinc finger proteins.

Africa Harvest is also developing GM seed that is resistant to pests. This would eliminate the need for farmers to spray pesticides onto their growing crops. Each year in parts of the world where safety equipment is not readily available or carefully used, the incidence of acute pesticide poisoning is high. In Sri Lanka, for example, the incidence is around 180 per 100 000 people (in comparison to 18.2 per 100 000 people in some developed countries).

Many small-scale farmers in Africa, however, do not want GM crops. They feel they already have effective agricultural practices that are more environmentally and farmer-friendly than GM. Using traditional farming methods, farmers throughout Africa have developed a great diversity of seed varieties bred for their flavours and nutritional value, and which have evolved with local pests and diseases and are adapted to different soils and weather patterns. Such diversity is far safer than relying on a single crop that may fail widely in an event such as a pest infestation or a drought, events that may be more likely as climate change progresses.

Of further concern is the control of seed exercised by some companies, which make it illegal for farmers to save seeds so that they are forced to buy GM seeds each year. Farmers in many countries, however, do see the benefits of GM seeds.

Fish oils



Rothamsted Research

Figure 3 *Camelina sativa*.

Jonathan Napier and his colleagues at Rothamsted Research are working on technology that could reduce the demand for wild-caught fish. Fish oils are known to protect us against cardiovascular disease by lowering plasma cholesterol levels and blood pressure and by slowing the formation of fatty plaques in artery walls. They are also important for development of nervous tissue, particularly the brain, in humans.

Rothamsted Research

Figure 4 Mackerel.

Humans do not have the metabolic pathways to synthesise these oils; we have to obtain them in our diet from oily fish such as salmon and mackerel. The oils are not actually made by fish, but by algae, and pass up the food chain via small fish that eat the algae and are eaten by larger fish. At present, farmed fish are fed with minced wild-caught fish. Prof Napier has modified *Camelina sativa* (a cousin of oilseed rape that is unable to hybridise with any wild relatives) by using a bacterium, *Rhizobium radiobacter*, that can inject DNA into plant cells. His team has inserted a fatty acid elongase gene from a waterborne moss and a fatty acid desaturase gene from a planktonic alga into *Camelina* so that it will make the fish oils. This crop can then be used to feed farmed fish, reducing the need for feeding so many wild-caught fish to farmed fish, and thus also reducing the accumulation of toxic mercury up the food chain into the larger fish.

For and against

The list of pro and con arguments below is not complete; you may have additional ideas. Many of these points are illustrated in the case studies above, others have been used by campaigners for and against the use of genetic modification.

Advantages

- Crop plants can be created with higher yields or improved properties such as drought resistance or salt tolerance, improving food security.
- Crops with herbicide resistance enable weeds to be killed more easily and yields increased.
- The use of agrochemicals and hydrocarbons can be reduced (e.g. crops that produce their own pesticides need no application of synthetic pesticides), with benefits for the environment and human health. A recent study reported that worldwide the use of GM crops has increased average yield by 22%, caused pesticide use

to drop by 37%, and led to an increase in farmers' profits of 68%. In Canada oilseed rape with a gene from barley introduced has reduced the use of nitrogen fertiliser by 40%.

- Waste and inefficiency can be reduced (e.g. the need to catch wild fish in order to feed farmed fish).
- Better nutrition is possible (for example food crops with increased levels of vitamin A or zinc can be produced).

Disadvantages

- Plant resistance to pathogens could stimulate more rapid evolution of strategies in pests to overcome this resistance.
- New genes for pesticide resistance in crops could transfer into related wild plants, leading to proliferation of superweeds resistant to herbicides.
- Ecosystems could be damaged by overuse of pesticides or the encouragement of monocultures.
- Monoculture (growing just one variety of one crop and losing genetic diversity) increases vulnerability to disease or changing conditions and thus reduces food security.
- Reliance on single technological solutions may discourage more diverse, lower-tech answers (e.g. improving health by increasing dietary variety with home-grown vegetables).
- Modified plants might be toxic to other organisms or stimulate an allergic reaction in humans if the inserted genes are expressed to produce allergenic proteins.
- Farmers – especially in the developing world – could find themselves economically trapped into buying GM seed, and the pesticides or fertilisers it needs, from the same company every year, regardless of price, instead of being able to save their own seed from year to year or to buy different items from different companies.
- Consumers who do not know much about genetic modification may be concerned that GM food is harmful: for example, that plants do not usually contain genes, that anything 'unnatural' is dangerous, or that 'foreign' DNA in the inserted genes will be expressed in people (in fact, all food we eat contains genes, and we digest most of the DNA with specific enzymes, nucleases and nucleotidases).
- Consumer resistance may require extra, expensive tracing and labelling for all foods.
- Some GM foods contain genes from animals. People who do not eat meat may not want to consume these foods.

Sources and further reading

Two videos are available on The Crunch website: 'Making fish oils in plants' (the genetic modification of *Camelina sativa* by Professor Napier and colleagues at Rothamsted Research) and 'Potatoes – research and the biotechnology of genetic modification' (work on potatoes genetically modified to carry a number of improved traits by Professor Jonathan Jones and colleagues at the Sainsbury Laboratory) **thecrunch.wellcome.ac.uk/schools**

Benefits and risks of the use of herbicide-resistant crops (UN Food and Agriculture Organization): **http://www.fao.org/docrep/006/y5031e/y5031e0i.htm**

Numbers dwindle at Mexico's mountain of butterflies: **http://www.theguardian.com/environment/2014/jan/29/monarch-butterfly-numbers-drop-to-lowest-level-since-records-started**

Monarch Lab, University of Minnesota: **http://monarchlab.org/biology-and-research/ask-the-expert/faq/**

List of pros and cons of Golden Rice: **http://occupytheory.org/list-of-pros-and-cons-of-golden-rice/**

Golden Rice™ project: **www.goldenrice.org**

Africa Harvest: **africaharvest.org/**

Occurrence of acute pesticide poisoning: **http://www.who.int/bulletin/volumes/86/3/07-041814/en/**

GM crops won't help African farmers (opinion): **http://www.theguardian.com/global-development/poverty-matters/2013/jun/24/gm-crops-african-farmers**

Monsanto's glyphosate pages: **www.monsanto.com/glyphosate/pages/default.aspx**

Friends of the Earth briefing on GM crops and food: **https://www.foe.co.uk/sites/default/files/downloads/gm_crops_food.pdf**

Food Standards Agency and GM foods: **http://www.food.gov.uk/science/novel/gm**

World Health Organization: Frequently asked questions on genetically modified foods: **http://www.who.int/foodsafety/areas_work/food-technology/faq-genetically-modified-food/en/**

Future Food, with a section on sustainability and technology: **http://futurefood2050.com/**

Sense about Science on GM (they also have other food-related subjects): **http://www.senseaboutscience.org/subjects.php?action=tag&id=56**

Food Climate Research Network (FCRN) including a library of research: **http://www.fcrn.org.uk/**

UN Food and Agriculture Organization, climate-smart agriculture: **http://www.fao.org/climate-smart-agriculture/72616/en/**

Rooftop garden productivity case study: **http://ec.europa.eu/environment/integration/research/newsalert/pdf/rooftop_gardens_could_grow_three_quarters_of_citys_vegetables_409na2_en.pdf**

Questions

1. Using the information you have gained through reading the case studies and some of the references above, prepare a survey to find out how much people know about genetic modification and how they feel about eating GM food. The survey should be quite short for ease of analysis and to reduce the time needed by respondents. Use the results to discuss in class or prepare for a debate with your colleagues or wider school community.
2. As a class, carefully phrase a proposition concerning the pros and cons of genetic modification that you can debate. Here are some ideas, but you will have your own:
    - GM foods are unnatural 'Frankenfoods' that will do more harm than good.
    - GM foods must be the mainstay of our response to the problems of food security.
    - Anti-GM campaigners are restricting poor people's access to healthy food that they desperately need.
    - There is no world food shortage, only inefficient farming and poor distribution, so GM crops are a bad answer to the wrong problem.