Genetically Modified Crops

There has been much media attention on fears about genetically modified (GM) crops, including concern for human health and wildlife habitats. This briefing paper first introduces the science of GM and then considers particular applications.

GM science and technology

First we shall look at some basic GM science and then consider intrinsic ethics, by analogy with plant-breeding and other technologies.

What does 'genetically modified' mean?

The characteristics of all living things are based on Deoxyribonucleic Acid (DNA), a long thread-like molecule found in every living cell. The total DNA within a cell (genome) can be conceptually divided into regions called genes, each gene being the plan for one protein or part of a protein. DNA acts as a template to make the proteins that control the thousands of functions in any organism.

Recent research has made it possible to isolate individual genes from a genome and then multiply them in bacteria or viruses. Genes can be changed and then – along with attached bacteria or virus DNA (vector) – the 'transgene' can be inserted into the DNA of individuals of the same or another species. Only a few individuals take up the foreign DNA, so a 'marker' gene is also inserted to enable scientists to trace those plants and grow them on to maturity. Below are two examples of the types of change that can be caused by genetic modification of a plant.

Transfer of a characteristic

A gene from bacteria is inserted into oilseed rape to produce plants resistant to a herbicide. Fields can be sprayed with that herbicide while the GM rape is growing, killing all other plants and achieving a stricter monoculture.

Inversion of a characteristic

Ripe tomatoes normally have a protein that makes them begin to soften. A gene for this protein was isolated, inverted and reinserted, a process called 'antisense'. The aim is to slow the natural softening, and so produce fruit that endures long-distance transport or storage.

Letters, words and recipe books

DNA can be said to have an 'alphabet' of four chemical building blocks, designated A, T, C and G. These are linked to make DNA chains.

A **gene** can be likened to a word. It carries a very specific piece of information. Words are made up of the letters of the alphabet, and a gene is made up of the four building blocks, the order determining the information carried. A gene may contain thousands of 'letters'.

A **genome** is like a recipe book: it carries large amounts of information, thousands of genes. Just as the information in a recipe book might tell us how to make many different cakes, the genome tells the body how to make proteins.

Intrinsic ethics of GM crops

If DNA is the recipe for life, and if God's role is like a Delia Smith writing the recipe book, do we have a right to rewrite the recipes? And if so, to what extent, and in what ways?

A biblical perspective is that humans are made in the "image of God", and should be creative within creation. Developing a plant's genetic potential is similar in principle to formulating new chemical compounds and new materials.

Breeders have been directing the genetic make-up of plants for thousands of years. They inspect the variants which appear naturally within every kind of plant, and cross individuals by means such as moving pollen between flowers. When offspring mature they select ones that display the desired characteristics. Breeders work with the God-given potential for genetic variability that is naturally present within each distinct kind of plant.

New powers, new risks

Natural cross-fertilisation is designed to combine the DNA from two parents. For plant-breeders this is a problem, as a cross can incorporate many undesired characteristics that can then only be removed by crossing back to the key parent. Genetic engineering bypasses this constraint by direct manipulation of the genome. Boundaries between different kinds of plants, and between plants and other creatures, can now be crossed. Gene transfers involving animals raise ethical issues beyond the scope of this paper, and these are tackled in Briefing no.6: *Christians and Genetic Manipulation: Are We Playing God?*

Gene transfer between widely differing species can occur in nature, though the gene donors are restricted to viruses and bacteria. GM techniques involve the creation of new vectors designed to carry genes across multiple species boundaries, and this novelty has led to fears that there may be unforeseen risks.

A bacterium called *Agrobacterium* causes disease in a range of plants by transferring a portion of its own DNA into the plant's genome. This causes the plant to produce galls and food for the bacterium.

Risks to human health?

DNA inserted in plants is not harmful to consumers. There are, however, concerns about some of the gene products, and possible indirect effects.

Allergens and toxins

A gene from brazil nut put into soybean was shown in tests to cause a reaction in people allergic to brazil nuts. Such allergen problems have also been noted in plant breeding, where safety testing is not mandatory. This highlights the need for regulated testing of all new food crops. Toxicity testing for GM crops is on the one hand easier than in traditional plant-breeding as only a few genes are added, but on the other hand more problematic where genes have been brought in from plants with little history as human foods.

Antibiotic resistance

Antibiotic resistant genes from bacteria were used as ‘markers’ and this has introduced a risk of passing antibiotic resistance into human gut bacteria. Their use in new GM developments is rare as alternative markers, such as genes that fluoresce or react with certain stains, are now more used. Markers are not essential once plants reach field trials, and could be removed. Clearly, antibiotic-resistant markers in existing GM crops should now be removed. Also, pharmaceutical GM crops should in general be strictly segregated from food crops in order to avoid cross-pollination between them.

Emergence of virulent new viruses

In addition to a marker gene and a transgene, a short region of DNA called a promoter, that “switches on” the transgene, has to be included in the DNA inserted in the plant. There is concern that promoters derived from viruses could recombine with existing viruses and form new virulent viruses. Research into alternative non-viral promoters is required.

One commonly used ‘promoter’ is derived from cauliflower mosaic virus. Because it is related to HIV this has led to fears of a new virus affecting humans, but in this case the fear is unfounded as this mosaic virus is widely present in food crops.

Applications

Even if we judged that many GM applications were wrong, we should not reject the science itself. Just as nuclear technology can be used for weaponry but also for energy, so also here the enemy is not science but rather the ‘powers’ that abuse it (Ephesians 6).

In any technology the aims of applied research are controlled by funding, driven by motives ranging from greed at the expense of public good, through to altruism. Even where motives are good, projects can be misguided: there are differing worldviews and analyses of economic and environmental needs.

In the paragraphs that follow examples are presented of both advantages and risks in different types of use and in some specific applications.

Biodiversity and farming

Farming needs and practices vary widely in different parts of the world. As loss of habitat is a key cause of biodiversity loss, a large global extension of the farmed area is not desirable, though climate change might make large transfers of land-use essential. GM technology introduces the possibility of planting crops on alkaline, saline or very dry soils.

South American scientists have made GM plants that grow in alkaline soils and leach natural acids.

Traditional intensification also has limitations, partly because whereas in recent decades big yield gains have been achieved by a narrow optimisation for productivity, any future growth is likely to be limited by global systems such as the nitrogen cycle.

Some directions in GM research seem to run counter to this, such as dwarfing from NORIN10 genes, which is designed to enable higher fertiliser inputs before physical collapse of the crop under gravity.

There is scope for GM crops where nutritional return can be increased without intensification or extension, and the following types of application may do this.

1. Reducing spoilage during storage and distribution.

2. Increasing the nutritional value of the edible crop, or removing toxins from crops such as cassava.

3. Reducing losses due to disease and other stresses.

Herbicide-tolerant GM crops

Best practice for farming is to integrate production and conservation of biodiversity in each field or area, rather than having monoculture surrounding isolated protected patches.

One major type of GM application seems regressive in this respect. In 1998 about half of global GM research investment went into in the development of crops tolerant of herbicides.

The rationale is that this allows herbicides to be applied at moments when other species are most vulnerable, achieving in theory a near-complete elimination of other species without damage to the designated crop species.

On the separate environmental issue of whether this will reduce the total global usage of herbicides there is controversy. It may reduce the volume of herbicide used per unit area, though this needs confirmation by long-term studies, but it could also lead to herbicides being used on a larger proportion of farmed lands.

Farmers can be tied to a particular brand, especially if the seed and herbicide are owned by one company, as in the case of Monsanto and Round-Up, a wide-killing herbicide. In many cases this dependency is reinforced by seed sale contracts.

Insects and disease resistant GM crops

GM insecticidal crops can be beneficial to wildlife. As toxins are contained inside the crops rather than being sprayed this avoids drift into field margins and hedgerows. Insecticidal crops very specific to certain pests could be used to preserve non-pest insects, although in real cases commercial pressure tends to widen the insecticidal spectrum of branded GM crops so that they can be used in more varying contexts.

> A study in the USA described how caterpillars of the Monarch Butterfly suffered when doused in pollen from GM maize. It has yet to be confirmed whether pollen levels used in the laboratory reflect those found in the field. It is however possible to engineer plants in which the toxin gene is turned ‘on’ in the leaves but ‘off’ in the pollen.

As the effect of an insecticidal GM crop is constantly present in the crop throughout growth rather than intermittently sprayed, there is a concern that insects will be completely absent while the crop is growing. This would affect beneficial insects as well as pests, and small rodents and birds could suffer lack of food.

Ironically, whereas in initial years of use insects may almost totally disappear, over the longer term there is a danger that *continuous* presence of the toxin in plants will lead to pest insects becoming resistant to the toxin. If so, the reduction of inputs of insecticides or fungicides may turn out to be only a temporary benefit of the GM crop’s novelty.

> A bacterium (*Bacillus thuringiensis* or Bt) makes a natural insecticide that organic farmers use as a spray. The same insecticidal Bt gene has been inserted into some GM crops. Organic farmers are concerned that the eventual result will be insects resistant to Bt, making the spray useless.

Terminator genes

Most of the world's farmers save seed from their crop to sow in the following year. GM crops have been developed with non-germinating grain, which would stop farmers saving seed. It is uncertain whether this ‘terminator’ technology will be commercially developed, but there are as yet no legal restraints.

Monopoly and biodiversity

Globally there is great value in indigenous breeding knowledge of plants adapted to particular ecological niches. Advantage is often to be had from multiple crops in each field, and simultaneous cultivation of several varieties of each crop. The need for corporations to recover the high investment in each GM variety exerts a pressure for a smaller number of varieties to be used over larger land areas.

Accidental gene transfer

Genes for herbicide resistance can be passed by GM crops into related weed species, and this can lead to a variant ‘super-weed’ resistant to herbicide.

Also, if for example salt-tolerance were transferred from GM crops to a wild species, its ecological niche might expand and suppress existing biodiversity.

> Oilseed rape often grows alongside Charlock, a closely related species. GM rape could cross with it to produce a herbicide-resistant weed. In trials in the USA, crosses have been reported between oilseed rape and brown mustard.

Ecological impact of the GM crop itself

Many ecologists regard the introduction of an alien species into an ecosystem as a good analogy for the release of a GMO. It is hard to predict in advance which alien species will cause ecological problems.

There is also some controversy about ‘gene-stacking’ which is when additional transgenes unintentionally get into GM seeds, perhaps during seed production.

> On trial fields in the UK, a GM beet tolerant to the herbicide glufosinate was found to be also tolerant to glyphosate. As beet can be weeds in subsequent crops, more powerful herbicides might be needed to control the ‘gene-stacked’ GM beet.

Social and political issues

Freedom and choice

To enable each individual to make their own choices, all foods where genetic modification has been used in the process must be clearly labelled. There is also a concern for those who want to grow or eat non-GM crops in that it is very difficult to ensure that a crop is ‘GM-free’ because of risks from cross-pollination.

Honesty and communication

One of the ironies of the GM debate has been that, in the shadow of BSE, the media focus has been on direct risks to human health by consumption, rather than on biodiversity and justice issues.

Many problems, such as antibiotic marker genes and cross-pollination, could be solved but further research is needed. Pressure on GM companies should focus on using existing technology to reduce risks in current and future crops.

Many of the field trials in Europe aim to study the impact of GM crops on the local environment. So far their experimental designs have failed to meet the safety expectations of, for example, English Nature, but safer methodologies can be envisaged.

Commercial and public research

Much good work is being done at smaller, less commercial, research stations. Some institutions in the two-thirds world patent GM technology but offer it free to poor farmers. It is notable that two applications often cited as 'good' uses of GM – rice high in vitamin A, and crops resistant to RYMV (rice yellow mottle virus), which may protect against crop failure in sub-Saharan Africa – have both come from non-commercial research.

Opportunity cost

Could something better be done with the money? We should be sceptical of Utopian claims. Plant-breeding is not simple upward progress, but often requires trade-offs. Wild plants and old varieties remain valuable because in a different economic context they can again be useful. Projects such as saving seed samples of existing diversity should be higher priorities than any new GM research.

There is a clear role that the Church can take in calling for the wise use of science and technology, whilst protecting the poor and vulnerable, as well as wildlife and the environment.

Conclusions

1. GM crops may bring substantial potential benefits; there are also associated risks which need to be carefully and adequately evaluated.
2. Release of new GM crops should not be allowed unless it has been demonstrated that there are clear advantages to the environment or to society, which outweigh the dangers.
3. Strong international regulations need to be set up to control GM developments, and to protect the vulnerable and the environment.
4. Communications between scientists, public, media and multinationals need to be improved.
5. Improvement of existing GM crops, such as removing antibiotic markers, should be made a priority in research ahead of new developments.
6. Clear labelling for consumers is essential.

Further reading

Bruce, D. and Bruce, A. eds. *Engineering Genesis*, (London: Earthscan, 1998).

Reiss, M. and Straughan, R. eds. *Improving Nature - The Science and Ethics of Genetic Engineering*, (Cambridge: Cambridge University Press, 1996).

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The *John Ray Initiative* promotes responsible environmental stewardship in accordance with Christian principles and the wise use of science and technology. JRI organises seminars and disseminates information on environmental stewardship.

Inspiration for JRI is taken from John Ray (1627-1705), English naturalist, Christian theologian and first biological systematist of modern times, preceding Carl Linnaeus.

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