SUPER CROPS

Pain and Promise of Genetic Engineering

The world is moving fast towards replacing natural plants with genetically-modified (GM) plants. The promises of GM agriculture are vast, but so are the dangers. The London-based Panos Institute investigates into a major ethical issue

GENETIC experiments in agriculture are nothing new. For centuries, farmers around the world have selectively bred livestock and crop plants in order to produce strains with improved characteristics. But major changes have been occurring during the past decade, both in the methods being used and in the identity of those working to produce these novel strains.

To date, most varieties of crop plants have been developed either within farming communities or by publicly funded agricultural research institutions. Both farmers' traditional selective breeding techniques and conventional institutional breeding programmes use the natural variation within plant species to develop improved strains. This method has now been augmented by molecular biology techniques, which allow the introduction into plants and animals of entirely new characteristics, including genes originally found in unrelated plants, animals or micro-organisms.

The physical form and chemical composition of a typical crop plant is determined by up to 80,000 genes, or sections of DNA found in the nucleus of all cells. Genetic engineering enables scientists to insert new genes into an individual plant cell, which is then grown in tissue culture and can be used to regenerate full sized plants.

Now public funding for agricultural research institutions is dwindling, and the private sector is taking the lead in research and development of new seeds using the new genetic engineering technology. The principal actors are transnational 'life industry' corporations, whose interests cover the food chain from seed distribution through the manufacture of herbicides and insecticides to food production.

Genetic engineering is moving fast and the stakes are high. It requires big investments, and it raises great hopes and fears. Its supporters expect it to bring great benefits to the environment, food producers and consumers worldwide, while its opponents fear dangers to the environment and human health and negative impacts on small farmers. It is too early to know whether either the benefits or the fears will materialise, but meanwhile the technology raises new questions of science, law, ethics and economics which should be thoroughly debated around the world.

An estimated 30 million acres (12 million hectares) of genetically modified (GM) crops were sown in 1997, up from 4-6 million acres in 1996. The overwhelming majority of this land is in the USA and Canada, but GM soya beans have also been grown in Argentina. The first commercial GM crop in Europe is due this year: between 1,000 and 2,000 hectares of maize with resistance to the European corn borer is expected to be planted in France and 15,000 hectares in northern Spain. Meanwhile, non-commercial trials of GM crops are taking place in many countries throughout the world.

So far 64 GM crop varieties have been approved in the USA and Canada, 20 in Japan and eight in Europe (with applications pending on a further 13 products). However, the European authorities have only given conditional approval to the new technology. Only one of the authorisations so far allows large scale commercial production. The licence for Monsanto's Roundup Ready soya only allows the beans to be imported and processed within the EU, while in two member states, Austria and Luxembourg, there are outright bans on all GM crops.

The attitude of the European regulatory authorities reflects widespread public concern about the use of GM crops in food production. The strength of feeling varies between different countries, but even among many people who accept the value of genetic manipulation for producing new medical treatments there is uneasiness about the 'unnatural' character of GM food.

THE INDUSTRY CASE

THE proponents of biotechnology claim that it will transform agriculture, giving us the ability to 'design' crop plants to produce increased yields in difficult conditions with far less reliance on chemical inputs. Their vision is of GM crops as a clean and sustainable solution to the problem of food security for the world's growing population in the 21st century. Monsanto, the world's largest GM seed company, foresees three waves of beneficial products :

"The first consists of genetically modified crops which are resistant to insects and disease, or tolerant of herbicides. These will allow farmers to meet the growing demand for food from a population set to double in size over the next 50 years. The second wave, due to begin in five years' time, will see genetically induced 'quality traits' in food, such as high-fibre maize, or high-starch potatoes, some of which will help doctors to fight disease. And in the third wave, plants will be used as environmentally friendly 'factories' to produce substances for human consumption".

These are some of the environmental benefits the industry expects :

Drought tolerance

Water shortage and the increasing salinity of large areas of arable land are major constraints on agricultural productivity in many developing countries. If scientists can genetically modify plants for increased tolerance to these factors, GM crops could have significant beneficial effects on global food production. Scientists in Spain and the UK have reported success in producing modified strains of crops including rice, melons, tomatoes and barley, using genes extracted from yeast which improve the plants' ability to deal with excess sodium salts.

Need for herbicides

Among the first wave of GM crops have been several varieties of seeds resistant to a herbicide, glyphosate. The industry maintains that the new seeds will help farmers increase yields by improving weed control: the resistant crop would be the only plant still standing after the herbicide is applied. So far the most widely grown GM crop is a variety of soya bean produced by Monsanto which is resistant to the company's own glyphosate-based herbicide, Roundup. 'Roundup Ready' soya beans have been grown in the USA, Canada and Argentina. Monsanto says the combined use of its seed and herbicide will reduce the total number of sprays needed to control weeds, and overall chemicals usage will go down by a third.

Reducing soil erosion

Monsanto also claims that GM crops will counter land degradation through the loss of topsoil. It estimates that 25 billion tons of topsoil is lost annually around the world. It says Roundup can be used as part of a no-till farming system, which eliminates the need to plough land before planting. The residue from the previous crop is left on the field and the new crop is sown by dropping the seed into holes made by a seed drill. "Because the soil is not disturbed or exposed through ploughing, it is much less susceptible to erosion from both water and wind. No-till has been shown to decrease erosion rates by 90 per cent and nutrient and pesticide run-off by 70 per cent over conventional tillage."

Monsanto says these methods are particularly useful in areas of poor quality, marginal land. An example is the Bagumbayan area in the southern Philippines. The area is mountainous and was used for commercial logging until the late 1980s. Then the area was settled by subsistence farmers whose 'slash and burn' farming methods caused further erosion and depleted the already unproductive soil. The company sponsored a project to encourage conservation tillage and intercropping, in which maize was grown between rows of rubber trees. It says that using Roundup-resistant varieties has allowed farmers to control weeds without tillage, which would have contributed to the erosion problems. Since the new technique was used on 12,000 hectares, farmers' income has increased six-fold and the Philippines authorities are funding further development of the system in another 10,000 hectares, says Monsanto's regional manager Jade Jarbadan.

Insect resistance

A major target for development has been varieties of genetically modified plants which contain their own insecticide to destroy common agricultural pests. Several companies have developed strains of maize, cotton and other crops containing a gene from the naturally occurring soil bacterium *Bacillus thuringiensis*. This produces and protein called the Bt protoxin which is lethal to insects feeding on the plant. (Bt can also be used directly as an insecticide spray and has been highly effective for over 40 years).

Strains of potatoes were launched commercially this year in the USA which repel attacks by two of the major causes of losses, the Colorado potato beetle and aphids which transmit leaf roll virus disease. Replacing chemical sprays with genetic resistance will produce considerable environmental benefits, according to Monsanto's technology director Robert Horsch. Spraying is expensive and inefficient since most of the active ingredient never reaches the target pest and simply adds to the amount of potentially harmful chemicals circulating in the environment. Moreover, tractors or aircraft are used to distribute the spray, and he calculates that if every US potato farmer switched over to the new variety it would save over 1,300,000 litres of fuel.

THE CRITICS' CASE

A growing coalition of dissenting specialists, farmers, citizens' groups, scientists and ordinary consumers, North and South, is becoming vociferous in its warnings of possible dangers from GM crops and the need for caution — at least — in their introduction. The criticisms range from challenges to the scientific assumptions of the technologies, through questions about the motivations of the biotechnology industry, to arguments that such meddling with the genetic make up of plants is immoral or sacrilegious. Environmental campaigners in Europe are so concerned about the potential dangers of GM crops that they are prepared to break the law to disrupt the field trials of them. There have been many instances during 1998 of experimental crops being destroyed by activists in various countries including Germany, the Netherlands, the UK and Ireland.

Bad science

Some critics believe that genetic engineers will not be able to deliver on their promises because the genetic structure of plants is so complicated that scientists cannot yet fully understand and modify it. For example, these critics doubt whether it will be possible to modify crops reliably for salt tolerance. Salt metabolism is dependent on an interaction between several different genes. The more genes involved in a GM plant, the more unpredictable the results. Sometimes the genes simply do not work, or they may produce unexpected results. Some researchers themselves are cautious about the prospects of useful changes made to cells in the laboratory surviving when the plants are grown outside in the field.

GM crops, just like conventionally developed new varieties, will undergo field trials before they can be commercially released, which should reveal unexpected behaviours. But in 1996, in the first commercial growing season of Monsanto's Bollguard cotton, the pesticide effect of the engineered Bt was not sufficient to kill off all pests throughout the season, as the company had promised. Dr Mae-Wan Ho, of the UK's Open University, attributes this failure to unpredicted changes in the behaviour of the Bt gene. In 1997, 20 per cent of the first commercial crop of Roundup Ready cotton suffered deformed bolls and bolls dropping off early. "Unrelated multiple side-effects of introduced genes cannot be predicted in advance and are not always visible or easily detected," notes Dr Ricarda Steinbrecher of the Women's Environmental Network.

Ecosystem dangers

Besides having doubts about genetic engineers' capacity to achieve reliable results, many critics hold that the GM technologists are too focused on the specific crops they are developing, and do not pay sufficient attention to the wider environmental context in which the crops will be grown. Even organisations which generally welcome the new technologies have expressed doubts about moving too fast. In its evidence to a recent UK Parliamentary investigation, the British National Farmers' Union recommended compulsory monitoring for up to 10 years after commercialisation for all genetically engineered crops to ensure that there are no unexpected ecological impacts.

There are concerns, for instance, about the long-term effect of crops with built-in pesticide properties. One possible effect is the appearance of Bt-resistant insect pests. It is feared that insects that are constantly exposed to the Bt protoxin will eventually become resistant to its effects, in the same way that bacteria mutate to develop immunity to the effects of medical antibiotics. The US government takes the threat seriously and insists that GM crops should be grown alongside conventional crops to minimise the risk. Some observers believe that resistance has already developed. According to reports from the non-governmental organisation (NGO) Genetic Resources Action International (GRAIN), studies carried out in the USA are demonstrating that resistance to Bt is likely to develop far faster than Monsanto's scientists have claimed and that insects resistant to Bt are already present in the USA and elsewhere in the world.

Another fear is that the Bt gene may be an imprecise weapon which affects beneficial insects as well as pests. The US Institute for Agriculture and Trade Policy reports that: "In Thai field tests of Bt cotton, 30 per cent of the bees around the test fields died. The bees are necessary for the pollination of flowering plants and the production of honey."

There is some evidence that introduced genes may 'jump' into other organisms, with unpredictable and probably uncontrollable results. For instance, plants modified to contain genes from crop disease viruses might exchange these genes with other viruses, generating entirely new viral strains with unpredictable properties. Scientists from agriculture Canada have demonstrated this possibility. They developed a strain of cucumber mosaic virus lacking the gene for a specific protein needed to infect new plant cells. They then took an equivalent gene from another virus and inserted it into the host plant's DNA. In plants artificially infected with the disabled virus, new and fully ineffective viruses appeared within 10 days. "This appears to be the first time anyone has shown recombination between two different kinds of viruses within a plant," warns *New Scientist* magazine. "The risks may be much higher than biotechnology companies want to admit."

Environmentalists have also voice concerns about the transfer of engineered resistance genes' to related wild plants, producing new 'superweeds'. Dr Beatrix Tappeser of the Institute for Applied Ecology, Freiburg, Germany maintains that there are several scientific studies to show that this is possible and that the results could have "disruptive effects on the endemic flora (i.e. natural plant life) and agriculture." According to Topsy Jewell of the Pesticides Trust, "this could be particularly significant in countries where crops have weedy relatives. In the USA, where many of the transgenic crops are being forged, there are no weedy relatives of soya beans, maize, wheat or cotton. Weedy relatives of these crops, however, exist in other regions where the genetically modified crops are targeted, including Central America, Asia and the Middle East."

Reliance on chemicals

Another set of concerns has been expressed about genetically engineered herbicide resistance. Will it reduce the use of chemicals, as the industry claims, in the longer term? An analysis by the Pesticides Trust on behalf of the environmental campaigning organisation Greenpeace argues that the introduction of herbicide-resistant varieties will alter the pattern of herbicide use but will not significantly change the overall amounts used. If it leads to greater use of glyphosate, this will damage other crops and have adverse effects on wildlife, including beneficial insects such as ladybirds. The compounds can remain active in the soil for long periods, and can contaminate water. The report points out that the compound is highly toxic for fish, which form an important part of the protein available to the population of countries such as Bangladesh. "In the end, the introduction of herbicide-resistant soya has more to do with competition for market share of agrochemical products than sustainable agriculture," it concludes.

Planting of a GM herbicide-resistant crop may lead to over-reliance on a single herbicide.

According to Dr Steinbrecher of the Women's Environmental Network, "If spraying occurs regularly, there is every reason to believe that weeds in or near fields of genetically engineered crops would develop resistance to the herbicide — as weeds become resistant, higher and higher doses of herbicide would need to be used, leaving larger and larger amounts of chemical residue on the crops." In spite of earlier claims by scientists that it would be virtually impossible for weeds to develop resistance to glyphosate, resistance to the herbicide has appeared in ryegrass in Australia. It now seems that multiple uses of glyphosate in a single season provide the ideal conditions for weed resistance to evolve.

Loss of biodiversity

Another area of concern is the likely increased loss of biodiversity as a result of the introduction of GM crops. At present, many small farmers in developing countries maintain a rich diversity of plant varieties. In India alone, 50,000 varieties of plants are grown, and one survey found 70 different varieties in a single village in the north-east of the country.

These plants all show different characteristics and can survive under different conditions, so the genes they contain provide insurance against drought or disease — both for the local farmers and, ultimately, on a global scale. Replacing this richness of local varieties with vast 'monocultures' of a single variety leaves the crop vulnerable to attack by pests or disease.

Monoculture of conventionally bred crops has already demonstrated these dangers. For instance, the US maize crop was devastated by a fungal disease called corn blight in the 1970s and in 1975 Indonesian farmers lost half a million acres of rice to damage caused by the rice hopper insect. The promotion of GM crops is likely to increase the tendency to monocropping with a limited range of genetically uniform commercial varieties. If the local varieties around the world are lost as a result of the spread of commercial varieties, the range of genes available to feed the world is drastically reduced.

Health risks

Opponents also fear that GM crops may pose risks to human health. Fears focus on two main issues: the risk of transplanted genes producing proteins in the plants which may cause allergic reactions in people eating the food, and the presence of genes which could produce resistance to antibiotics. These have been used as marker genes during genetic modification, attached to the target gene to identify cells containing the new gene element: when exposed to the antibiotic the normal cells die but those with the marker gene survive. The antibiotic-resistant genes could be picked up by harmful bacteria, which would clearly reduce the range of drugs which can be used to treat disease. (In fact, genetic engineers have recognised this danger and are ceasing to use antibiotic resistance markers).

The profit motive

Finally, critics are alarmed that genetic engineering is being developed and promoted primarily by private corporations, and that with recent consolidations in the 'life industry' sector, a few giant corporations have control over a large proportion of the germplasm, agricultural processes and distribution systems needed to feed the world. Food is a basic right, these critics argue, for the poor as well as the rich, and it should not be in the hands of companies whose prime motivation is profit rather than the good of humanity.

Birth of the Super Seed

Key events in the development of Genetially-Modified crops

1953: Crick and Watson (Cambridge, UK) unravel the structure of DNA, the compound which encodes the genetic information of all plants and animals.
1975: Genetic engineering was made possible by the development of enzymes (restriction endonucleases) that enable scientists to cut DNA at precise points. In effect the enzymes are like 'molecular scissors,' tools which allow DNA to be cut and spliced between different cells.
1976: First attempts at producing genetically modified plants.
1982: First precise engineering of genetically modified plants
1988: European Union begins attempts to introduce a directive covering patents on genetically modified organisms.
1992: In the USA, Agracetus, a biotechnology firm owned by the US chemicals manufacturer W R Grace, receives a broad-ranging patent covering all genetically modified cotton.
— Calgene in the USA obtains a patent for FlavrSavr, a tomato modified to delay ripening and maintain its freshness.
1994: US Patent Office changes its mind and revokes the patent granted to Agracetus for genetically modified cotton. The case continues...
— Products containing FlavrSavr tomatoes go on sale for the first time in US supermarkets.
1996: First large-scale commercial planting of GM crops. Attempts by the US to export genetically modified soya cause protests from European environmentalists and consumer groups.
1998: European Parliament accepts a redrafted directive on patenting.
— Delta & Pine Land Co receives a US patent on a method for producing plants with seeds which are sterile when replanted — the 'Terminator technology.'

What Monsanto Says

Robert Horsch, director of technology for Monsanto explains his company's position in the following way:

"The key contributions of biotechnology will be several-fold
• producing more food on the same area of land, thereby reducing pressure to expand into wilderness, rainforest or marginal lands which support biodiversity and vital ecosystem services;
• reducing post-harvest loss of food (caused by disease, pests and decay) and improving the quality of fresh and processed foods, thus boosting the 'realised nutritional yield' per acre;
• displacing resource and energy-intensive inputs, such as fuel, fertilisers or pesticides, thus reducing unintended impacts on the environment and freeing those resources to be used for other purposes or to be conserved for the future;
• encouraging reduction of environmentally damaging agricultural practices and adopting of more sustainable practices such as conservation tillage, precision agriculture and integrated crop management;
• stimulation of a new kind of economic growth : more benefit with less throughput and harm."

The Terminator

SHORTLY before its purchase by Monsanto, Delta and Pine Land Inc was awarded a patent on a gene modification which prevents saved seed from germinating. The technology, dubbed the 'Terminator gene' by the Canadian development organisation RAFI, has only been shown to work so far in cotton and tobacco, but the patent covers all cultivated seeds. The company has applied for patents in 78 countries and intends to make the technology available for licensing by other seed breeding companies. This first commercially available seeds are likely to be on the market some time after 2000.

Modern hybrids already don't reproduce reliably, so that many farmers who use them have to buy new seed each year. But this technology would introduce sterility to non-hybrid corps (such as what). It would prevent farmers saving some of their best seed as they have done since the beginning of agriculture. Currently 80 per cent of crops in the developing world are sown using farmer-saved seed. Though of course farmers will not be forced to buy new modified types of seed, critics fear that there may be increasing pressures on them to do so, catching them in a spiral of costly inputs, debt and dependence on the seed-marketing companies. The companies feel this will be a good thing for Southern farmers: "This development will broaden access to continuing agricultural improvements. The centuries-old practice of farmer-saved seed is really a gross disadvantage to Third World farmers who inadvertently become locked into obsolete (i.e. old-fashioned, low-yielding) varieties because of their taking the easy roads and not planting newer, more productive varieties."

There is also a fear that concentration of research on GM crops will widen the technology — and wealth — gap between small poor farmers and big producers. The new technology is designed to protect US industry from unauthorised use of its products and to increase sales of commercial seed. It could "increase the value of proprietary seed owned by US seed companies and open up new markets in Second and Third World countries", according to Willard Phelps, of the US Department of Agriculture, co-owners of the patent. Its inventors also claim it will encourage investment in biotechnology for developing countries, and thus provide farmers with more choice.

Thinking with the Stomach: Two Sides to GM Crops in Food Security

Positive ...

A MAJOR argument from the industry for continuing the rapid development and use of GM crops is that they will be the best means of providing food security for the world in the 21st century.

Food security — the state in which all people at all times have access to enough safe and nutritious food to maintain a healthy and active life — is still a distant goal. The past two decades have seen an increase of 15 per cent in the amount of food available for the world's population of nearly six billion, but according to the UN's Food and Agriculture Organisation (FAO) one in seven of the world's population are still chronically malnourished, including one in three children. At the World Food Summit in 1996, governments committed themselves to halving the number of hungry people by the year 2015. Moreover, global food demand is expected to go up by as much as 50 per cent in the next 15 to 25 years as a result of population growth and rising incomes.

The majority of analysts agree that the world needs to produce larger quantities of food (though most agree that the distribution of food is also a fundamental factor) without in the process exhausting and polluting our limited resources of land and water. Proponents believe that genetic engineering will make a major contribution to this goal. The Green Revolution of the 1960s and 1970s led to huge improvements in crop yields for rice and wheat, but its new varieties required substantial inputs of fertiliser, pesticides and water. It is now widely recognised that further progress along that road is unlikely to be sustainable.

Agrochemical companies maintain that GM crops will play a big role in sustainable agriculture by increasing yields, reducing the need to expand the area of cultivated land, and at the same time reducing the need for herbicides and pesticides. They are supported by many independent scientists including the Nobel Prize-winning agriculturalist Professor Norman Borlaug, a leading figure in the Green Revolution in the 1960s. He sees GM crops as a logical extension of the developments during the Green Revolution.

He accuses environmentalists of wanting to turn back the clock by insisting on technologies which were only adequate for supporting a much smaller world population than exists today. "I am particularly alarmed by those who seek to deny small-scale farmers of the Third World — and especially those in sub-Saharan Africa — access to the improved seeds, fertilisers and crop protection chemicals that have allowed the affluent nations the luxury of plentiful and inexpensive foodstuffs...While the affluent nations can certainly afford to pay more for food produced by the so called organic methods, the one billion chronically undernourished people of the low-income, food-deficit nations cannot."

...... or Doubtful?

However, it is now widely accepted that food insecurity does not result from an absolute world shortage of food, but has economic roots. Some analysts believe that the world already produces adequate food and can continue to do so with traditional techniques, but that the food is unevenly distributed. The single most important cause of hunger is poverty. The FAO, while emphasising that "low productivity in agriculture" is one of the principal causes of under-nutrition and food insecurity, identifies poverty and policy constraints as more important causes of low productivity than inadequate technology. "The causes and consequences of food insecurity and poverty are inextricably linked."

In this view of food security, expensive new technologies like GM will not address the real problem: indeed they might even make it worse. NGOs, farmers and researchers around the world are developing different new models for sustainable agricultural development which do not depend on expensive imported technology and which use the skills of local people. They believe that overcoming hunger and poverty calls for a wide range of measures, from debt relief to land redistribution, and that technical improvements must be geared to environmental sustainability and protection of livelihoods, not just to increasing yields. For example, organic and permaculture methods are successfully achieving yield increases where they are being tried around the world. "The FAO itself is calling for a new Green Revolution," observed an earlier Panos report. This "will focus more on small, resource-poor farmers, embrace equity issues and see farmers participation as essential for blending new technologies with traditional knowledge and for setting research agendas for the future."

Professor Swaminathan, one of the developing world's most respected agronomists and father of India's Green Revolution, believes firmly that genetic engineering will have an important role, as long as it is developed and introduced as part of a holistic vision of environmental and socio-economic sustainability. "Since there is no option in population-rich and land-hungry countries but to produce more per units of land, water and labour, there is need for technologies which can promote and sustain an ever-green revolution rooted in the principles of ecology, economics and social and gender equity. It is obvious that the challenge can be met only by integrating recent advances in molecular genetics and genetic engineering, information and space technologies, renewable energy technologies and management science with traditional technologies and ecological wisdom, resulting in appropriate ecotechnologies. There should be no relaxation of yield-enhancing research, since there is no other way of meeting global food needs."

But some doubt that genetic engineering is being introduced in the way Swaminathan would wish to see. They fear that the scientists and corporations who are making the running are focussing narrowly on the 'technical fix' aspect of GM crops, to the exclusion of socio-economic and environmental aspects.

Critics are concerned that GM crops might repeat some of the characteristics of the Green Revolution, in which higher yields were achieved at such a cost in inputs that smaller farmers' prosperity was not increased and indeed many were forced into debt and off their land. For one thing, the seeds of new GM strains will probably be hybrids or modified to have low fertility. Farmers would therefore be unable to keep seed, the traditional practice of most Southern farmers, but would be reliant on fresh seeds bought from commercial suppliers each season.

Another concern is that none of the GM crop varieties available so far is likely to be used to feed local people in Third World countries. Environmental campaigner George Monbiot points out that GM maize was developed primarily as animal feed. If it is grown in Africa it will be for production of meat to be eaten by local elites or exported to supply the developed world's appetite for animal protein. He believes that GM crops will escalate an existing trend in which land used by peasant farmers is swallowed up by large-scale commercial agriculture. Producing animal feed "is one of the engines of African famine, as land previously devoted to meeting local people's necessities has been expropriated to supply the rich world's luxuries." Most of the patent applications relating to genetically modified maize (quarter of all GM patent) are for modifications increasing the starch content so that it can be used for industrial applications.