Ethical issues and transgenic crops

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Abstract

To date, a large variety of transgenic crops have been developed. These crops have been modified to express traits such as tolerance to herbicides, resistance to insect pests and viruses and production of enhanced nutrients. Proponents of GM technology argue that these modifications can only be beneficial to humans, as they reduce harmful effects to the environment as well as enhance crop yields. Opponents, however, cite different studies and rebut these arguments. This paper addresses the ethical arguments most commonly cited for and against transgenic crops and analyses these issues.

Introduction

Genetically modified organisms (GMOs) or transgenics are organisms which have had their genetic message altered in a way that would not occur in nature. The technology for the creation of these GMOs was developed in the early 1970s (1) with the first modified organisms appearing soon after. Despite the large number of GMOs that have been created, it is the subject of genetically modified or transgenic plants that generates the most antagonism, particularly in Europe. The subject has become an extremely emotive one, polarising society into extreme factions, proponents and opponents with very few middle-of-the-road opinions. Consequently, many of the arguments are also strongly emotive, with journalists complicating the discussion with talk of 'Frankenstein foods' 'demon seeds' and 'rogue genes'(2). Other arguments have addressed the issue of playing God, the sanctity of nature and ownership issues.

The nature of genetic modification

Proponents of genetic modifications argue that humans have been altering the genetic make-up of plants and animals for centuries. By repeatedly mating plants and animals with desirable traits, humans have been increasing the yields, quality and content of various organisms (3). For example, Jersey and Guernsey cows have been bred for milk yield while Hereford and Aberdeen Angus cows have been bred specifically for meat production. More recently, in plants, this process has been accelerated by induction of mutations[1], the purpose of which is to produce changes in the genetic make-up of seeds which can then be selected and bred (4). In such plant breeding programmes, the most promising lines are selected while the rest are discarded. This is obviously a lengthy process which can take years, for the number of different lines (combinations) generated are virtually infinite.

It is however possible to reduce the generation times through the use of modern biotechnology techniques. With these methods, a single gene coding for a desired trait from any organism can be identified and integrated into the recipient plant's genome. The donor organism can be a plant, animal or microorganism and the transfer is not limited to organisms of the same species. At this point a genetically modified, recombinant or transgenic plant is created.

Producing transgenic plants

Various methods exist to produce transgenic plants, but that most commonly used involve the soil bacterium *Agrobacterium tumefaciens*. This bacterium contains a tumour-inducing plasmid, called a Ti plasmid, that can be used to transfer a desired gene into a plant. Once injected by the bacterium into plant cells, the plasmid contains a short piece of DNA called the T-DNA which leaves the bacterial genetic material and integrates with the plant's own DNA causing infection. Plant biotechnologists modify the Ti plasmid so that it can inject a segment of its DNA into a plant but does not cause uncontrolled growth. A selectable or marker gene is also engineered into the plasmid. This is usually a fragment of DNA that codes for resistance to an antibiotic such as kanamycin, and this will allow breeders to select positive transformants or plants that express the desired trait. Additionally, the foreign gene that the breeder wants to be expressed by the plant is also inserted.

Uses of genetic modification

Plants have been modified for a range of characteristics but the most

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[1] These include ionizing radiation γ-and X-rays, α-particles, non-ionizing radiation (UV-B light) and chemical mutagens such as ethyl methansulphonate, diethyl sulphate, nitroso compounds and sodium azide.

common traits are summarised in Table 1. These include the insertion of genes to make plants tolerant to herbicides and naturally resistant to pests or pathogens, to delay ripening of fruit and to improve nutritive qualities (5).

TYPE OF GENETIC MODIFICATION	DESCRIPTION
Herbicide tolerance (potato, tomato, rape-seed, tobacco)	Produced by inserting a gene from *Salmonella typhimurium* into plant cells. This gene makes the plant produce an enzyme with a single amino acid substitution (proline to serine) resulting in a decreased affinity for the herbicide glyphosate (5).
Insect resistant crops (corn, maize)	Produced by pasting a gene from the bacterium *Bacillus thuringiensis* into plant cells. The gene results in the production of a toxin called the Bt toxin (5).
Virus resistant crops	DNA coding for resistance to the leaf roll virus is inserted into potatoes protecting them from the corresponding virus (5).
Enhanced nutritive qualities (golden rice)	A series of genes coding for enzymes critical in the production of a particular molecule are inserted into the plant.
Slowing down of ripening	Ripening is slowed down by switching off the gene controlling the production of the enzyme polygalacturonase that causes cell wall degradation (5).

Table 1: Table summarising the main types of genetic modifications in plants.

Regulations in Europe, the Precautionary Principle and Risk Assessments

In the European Union (EU), the situation that is of greatest local relevance, the deliberate release of GM crops into the environment and their placing onto the market are closely monitored and regulated by various directives and regulations (6-15). An extremely cautious stance has been adopted, and only those crops that have satisfied the numerous obligations laid out within the relevant directives of the Acquis Communitaire are approved for release within the member states. A list of these can be viewed on websites such as the Belgian Biosafety Server (16).

When placing a new GM crop onto the EU market, regulations require that a notification be submitted to the State where release is to take place. The notification must include a risk assessment to detect any possible risks to the environment or human health (14)[2]. In making an assessment, the Precautionary Principle must be applied at all times. This principle, whilst avoiding dictating any direct actions required, is based on the rationale that in the event of an uncertainty, one must err on the side of caution to avoid harm. It is sufficient, therefore, for there to be a threat of a risk or harm for policy makers to reject a proposal.

The risk assessments used to determine whether a modified plant is likely to constitute a health or environmental hazard are described in the same Directive. Environmental impact assessments, for example, are intended to answer the following main questions:

- Can genetic alterations be transferred to other organisms and if so, what might the consequences be?
- Will the genetic alteration modify ecologically relevant properties of the organism?
- If a new genotype is added to the environment what will the consequences to the ecological community be?

Health assessments are intended to assess mainly the following questions:

- Is there a risk that a disease be transmitted to humans, animals or plants?
- Can the genetic alteration be transmitted to pathogens, facilitating the dissemination of infectious diseases?

Ethical arguments

Despite the regulatory systems operational within the EU, there still is great resistance to the introduction of GM crops and major debates whether GM crops should be used. The ethical arguments that are most often presented can be summarised into four main areas, namely:

[2] Modifications and contained use of microorganisms are also strictly regulated by the European Union, and the obligations of any operator are laid out in Directive 98/81EC (15). All directives referred to in this paper have now been transposed fully into Maltese law.

- Possible effects of transgenics on the environment,
- Possible effects on human health,
- Possible effects to reduce world hunger,
- Various general arguments.

Transgenics and the environment

Many scientists regard the ability of engineered plants to resist environmental stresses as less damaging to ecosystems and therefore as an ethical advance. Others regard this ability to target specific stresses as unnatural as the use of agro-chemicals. In deciding which argument carries more weight, one approach would be to look at which is more harmful in aggregate terms. For example, amongst the many crops that have been engineered to withstand herbicide, GM cotton requires just three sprayings per season compared to the 45 sprayings with broad spectrum chemicals used with traditional cotton crops (17). Surely, this should be considered as an ethical advance, especially in the light of the many environmental problems generated by the use of broad spectrum pesticides. Systematic opposition to genetic modification can also lead to inconsistency of argument. For example there are varieties of oilseed rape *(Brassica rapa)* that have been generated by conventional means to carry genes for resistance to two varieties of herbicides (18) and these are not opposed. However, if the same end is achieved through traditional means, one questions on what basis this should be regarded as ethically correct, particularly since the genetic modification has been the result of human intervention in both cases.

Opponents to the development and use of transgenic crops argue that transgenic traits such as herbicide resistance can be passed on to related species creating herbicide-resistant invasive weeds (19). There is evidence that transgenic crops and their genes can, in fact, spread through pollen dispersal (20) and this is one of the main concerns raised against the introduction of transgenic rape-seed. The risk of this happening would be expected to differ in different ecosystems. In Mediterranean ecosystems, for example, rape-seed is related to a number of important agricultural weeds and many wild relatives of the *Brassica* family, and so the risk would be expected to increase. Other factors that could contribute to increasing the risk of cross-hybridisation include the presence of an overlap of the flowering period of the cultivated plant and its wild hybrid, and whether successful crossings between the cultivated plant and its wild relatives appear regularly.

Another related issue is the concern that genetically modified organisms may contaminate conventional or organic crops. Farmers should be free to cultivate crops of their own choice, but accidental contamination by genetically modified organisms (GMOs) could result in loss of revenue, since farmers would then have to sell their product at a lower price due to the presence of GMOs (21). This issue is still being resolved by the EU Commission, but possible farm management strategies that could be adopted and recommended include the introduction of isolation distances between fields, pollen barriers, crop rotation and planting arrangements that cover different flowering periods.

In answer to fears that GM plants may transmit new traits to other plants, companies have adopted a strategy called the 'terminator technology' (22). This technology involves the engineering of seeds so that they cannot be collected at the end of one crop cycle for subsequent planting. Consequently, seeds containing the technology would not aggregate in the environment after a growth cycle. Opponents of the strategy have argued that this method disadvantaged the farmer by putting him under the control of large companies and precluding the use of home produced seed. Opposition to the technology was so strong that it was subsequently withdrawn by biotechnology companies. However, the need for a system to control gene flow is still deemed to be necessary. In fact, in Canada there have been cases where plants resistant to weed killers have spread to other crops on farms. A new technology dubbed the 'Geneguard' is being developed in the shape of a tobacco plant that can self-pollinate but cannot reproduce with any other plants (23). The premise behind 'geneguard' is simple. A modified plant is given two extra genes. Gene 1 blocks germination and is linked to the disease resistance gene, while Gene 2 stops Gene 1 working. If a plant accidentally crosses with other crops or relatives, the added genes separate[3] and each plant inherits only one of the two extra genes. Half the seeds die through failure to germinate while the other half live but do not carry the disease resistance genes. The system, which is still being perfected, is not without its detractors, who claim that poor farmers will not be able to breed their own varieties.

[3] Self-pollination obviously does not occur.

The transformation of plants with pest resistance is another area of transgenic technology that has been heavily criticised, as there are fears of unintended deleterious effects on non-target organisms. Unlike conventional agrochemicals, no studies that demonstrate these effects on humans or organisms higher up in the food chain exist. However, some studies such as that by Cornell University reported adverse effects when Monarch butterflies (*Danaus plexipus*) ingest Bt corn[4] pollen (24). Yet, according to Wolfenbarger and Phifer (25), none of the studies have addressed the rate at which larvae encounter the toxin in their natural habitat or how the risk of ingestion of these chemicals compares to the risk with traditional chemicals. Certainly, agrochemical control of crop pests is extremely inefficient, environmentally more harmful and damaging to bio-diversity, and hence ethically unsound and at least in this respect transgenic crops may offer a partial solution to the environmental problems seen with extended use of agrochemicals.

Transgenic crops and human hunger

A major argument presented in favour of transgenic crops by biotechnology companies is that transgenics are critical to reducing poverty and hunger in many third world countries (26, 27, 28,), as these result in better crop yields through the control of insect pests. However, this argument depends on the assumption that food shortage is the only cause of hunger and ignores other more complex issues that also affect food supply such as unequal distribution of land and water, environmental constraints such as drought, political issues and economic instability, patters of social hierarchy and poor health. Realistically, companies would want to see a return on their investments, and it would be highly unlikely that seeds would be distributed for free, or that companies would develop GM strains specifically for crops grown in third world if no foreseeable returns are expected. Moreover, it is unlikely that third world countries would have the human, financial and scientific resources and infrastructure needed to identify any potential impact of introducing GM crops on their flora and fauna. Poorer countries could consequently find themselves being used as a testing ground for the introduction of GM crops.

[4] The caterpillar of the *Danaus plexipus* actually feeds on milkweed, which, in some parts of the United States grows next to corn, and so there is the potential for some modified pollen to drift onto the milkweed.

Transgenics and human health

Another argument cited by opponents of transgenic crops is that transgenic foods may bear toxic or allergenic components. Franck-Oberaspach and Keller (29) reviewed many classes of toxins and allergens and showed that these are part of a plant's natural defence systems and are not specific to transgenics. Furthermore, the methods employed to produce transgenics use specific, well characterized vectors, and unless the foreign insert gene was taken from one of the classes of genes known to code for allergy generating proteins, there is actually less chance of transgenic foods being allergenic. In fairness, GM-derived foods are also subject to more stringent tests than conventional foods. Furthermore, in response to commercial demands, there is a concerted effort by food companies to genetically modify common allergenic generating foods such as soya to reduce the allergenic component (30, 31). As this would benefit a component of human society, should this then be regarded as an ethical advance?

Some opponents of transgenic varieties fear that antibiotic resistance genes such as those coding for kanamycin resistance may be passed onto bacteria present in the gut rendering future use of the antibiotic useless in the event of a bacterial infection. An organism's intestinal tract, however, is capable of digesting DNA into pieces that are too small to code for a functional protein. A related fear is that the inserted gene may be transferred to cells of the gut or the respiratory system. Again the same argument holds. However, the opposition to GM-derived foods is so great that in some countries it has led to the withdrawal of GM foods from supermarket chains and restaurants. As the same establishments also sell alcohol, fatty foods and cigarettes, their action, which has mainly been taken on the basis of sales and public perception, can hardly be regarded as consistent from an ethical point of view.

Another human health concern arises from the fear that the antibiotic resistance gene may be transferred from the transgenic plant to wild plant populations and hence to any bacteria that may infect that plant. These bacteria may then be advantaged in their natural environment. Although the World Health Organisation (WHO) has judged antibiotic resistance genes to be safe (32), there is evidence that gene escape can occur as a result of transformation using *Agrobacterium* as the gene vector (33). This has led the European Union to recommend that use of antibiotic marker resistance genes used in GMOs intended for market release, be phased out by 2004 and those used in other GMOs by 2008 (15).

Finally, human health already suffers from current agricultural techniques involving the use of agrochemicals. Women working in banana packing plants in Costa Rica, for example, suffer twice the rate of leukaemia and birth defects, while a fifth of the country's male workers are sterile due to exposure to dibromochloropropane (now banned). Commercial banana production also requires the application of up to 40 sprayings of fungicides per year to control the continual outbreaks of fungal disease such as black sigatoka (34). It can therefore surely be argued that it is ethical to produce a transgenic banana that would allow a reduction in the use of pesticides, for example by producing fungal resistant bananas.

Other arguments

One of the most common arguments raised by the general public is that the process by which GMOs are created is not natural and hence 'not good'. However, many beneficial processes ranging from water sourced from reverse osmosis plants to GM-derived medicinals such as insulin and artificially fattened livestock have been altered or developed by man. As to the point that natural is always best, we would not treat disease or combat plagues, sterilize water and so on. This would quickly lead to the extension of many health problems faced in third world countries to the rest of the world, rather than the advancement of the former countries to higher health standards.

Yet another argument raised against the introduction of transgenic crops is that farmers would be totally dependent on large companies for seed purchase and there is the fear that this would reduce agricultural bio-diversity. Resistance to increased globalisation is particularly high at the moment. Undoubtedly, GM crops are produced by a few major players and this control of food production is likely to meet increased resistance.

Conclusion

In conclusion there are no straightforward answers to any debate on GM foods. Undoubtedly they are unlikely to increase in popularity, particularly in today's economic climate where the business ethic is seen to prevail over concerns for human welfare. GM crops are also unlikely to reduce world hunger and be the panacea biotechnology companies claim.

The large numbers of GM crops that have been grown, harvested and used in food and feed material with no harmful effects would appear to discredit arguments that such crops are harmful to health and the environment. Moreover in future, food production will have to be increased, and present farming techniques, with their heavy dependency on application of agrochemicals, cannot be sustained without much more serious degradation of the environment, human health and loss of biodiversity. If GM crops can reduce some of these negative impacts, they represent an ethical advance.

References

(1) Old W.R. (1991) *Principles of Gene Manipulation. An Introduction to Genetic Engineering*. Blackwell Scientific Publications.
(2) Browne A. (2002) *Demon Seed or Saviour?* Issue Times 2-Features, April 20, http://www.timesonline.co.uk/article/0,,7-388923,00.html
(3) Gould S.J. (1996) *Dinosaur in a Haystack* Penguin Books. pp285-295.
(4) Lindsey K. and Jones M.G.K. (1992) *Plant Biotechnology in Agriculture*. Wiley Publishers.
(5) Anonymous. *Biotechnological Innovations in Crop Improvement*. Butterworth-Heinemann. (1991).
(6) EU Directive 94/730. EEC decision establishing simplified procedures concerning the deliberate release into the environment of genetically modified plants.
(7) EU Directive 96/281. EEC decision concerning the placing on the market of genetically modified soya beans (*glycine max*) with increased tolerance to the herbicide glyphosate.
(8) EU Directive 96/424. EEC decision concerning the placing on the market of genetically modified male sterile chicory (*Cichorium intybus L.*) with partial tolerance to the herbicide glufosinate ammonium.
(9) EU Directive 96/158. EEC decision concerning the placing on the market of a product consisting of a genetically modified organism, hybrid herbicide tolerant rape-seed (*Brassica napus L. oleifera).*
(10) EU Directive 97/98. EC decision concerning the placing on the market of genetically modified maize (*Zea mays L*) with the combined modification for insecticidal properties conferred by the Bt-endotoxin gene and increased tolerance to the herbicide glufosinate ammonium.
(11) EU Directive 91/596. EEC decision concerning the summary notification format.
(12) EU Directive 93/584. EEC decision establishing the criteria for simplified procedures concerning the deliberate release of genetically modified organisms.
(13) EU Directive 93/572. EEC decision concerning the placing of a product containing genetically modified organisms pursuant to Article 13 of Council Directive 90/220.
(14) EU Directive 2001/18. EEC directive on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220.
(15) EU Directive 98/81. EEC directive on the contained use of genetically modified micro-organisms.

(16) http://www.biosafety.be
(17) Duggan G.(2002) GM cotton. http://www.abc.net.au/m/science/ss/stories/s554430.
(18) Concar D. and Coghlan A. (1999) 'A question of breeding'. *New Scientist.* 27th February
(19) Kling J. (1996) 'Could transgenic supercrops one day breed superweeds?' *Science.* Vol.274. 180-181.
(20) Brookes M. (1998) 'Running wild.' *New Scientist.* 31st October.
(21) Anonymous. (2003) Commission to produce guidelines on issues of GMO crop co-existense. Cordis Focus no.217. 24th March.
(22) Hayes E. (2002) *Seeds of controversy.* http://abcnews.go.com/onair/CloserLook/wnt990802_hayes_story.html.
(23) Coghlan A. (2003) 'No Escape for Alien Genes'. *New Scientist.* 10th May.
(24) Hansen L. and Obrycki J. (2000) *Field deposition of Bt transgenic corn pollen: Lethal effects on the Monarch Butterfly.*' Oecologia, DOI 10.1007/s004420000502.
(25) Wolfenbarger L. and Phifer P. (2000) 'The ecological risks and benefits of genetically engineered plants'. *Science*, 290:2088-2092.
(26) Serageldin I. (1997) 'Equity and Ethics'. In *Ethics and equity in conservation and use of genetic resources for sustainable food security.* Proceedings of a workshop to develop guidelines for the CGIAR, Foz do Iguaco, Brazil, IPGRI. pp1-6.
(27) Gioia A.H. (2003) 'Biotech crops to feed a hungry world.' *The Malta Independent on Sunday.*15th June.
(28) Anonymous. (2003) 'GM crops can reduce poverty in the developing world'. *Cordis Focus* no 224. 30th June.
(29) Frank-Operaspach S.L and Keller B. (1997) 'Consequences of classical and biotechnological resistance breeding for food toxicology and allergenicity'. *Plant Breeding.* Vol.116, 1-17.
(30) Kleiner K. (2002) 'Engineering safer soya.' *New Scientist.* 14th September.
(31) Nowak R. (2003) 'Modern grass snuffs out sneezes.' *New Scientist.* 21st June.
(32) WHO (1994) 'Health aspects of Marker Genes in Genetically Modified Plants' : *Report of WHO Workshop in Geneva.* WHO/FNV/FOS/93.6.
(33) Robertson J. (1999) 'Ethics and transgenics crops: A review'. *Plant Biotechnology.* Vol.2. No.2
(34) Pearce F. (2003) 'Last days of the Banana.' *New Scientist.* 18th June.