GENETIC MODIFICATION

WHAT IS A GENETICALLY MODIFIED ORGANISM?

Genetic Modification (GM) is a biotechnology technique that changes the genes of an organism (plant or animal) to produce a 'modified' or changed organism. It is a relatively modern technology, made possible by the discovery of DNA in 1953. The first field tests were conducted in 1987 on plants engineered to withstand frost, and the first 'engineered' food (a tomato paste) was licensed for sale in 1992-93.

HOW DOES GM DIFFER FROM CONVENTIONAL BREEDING?

Traditional (mutation) breeding involves finding favourable traits within species and crossing them with the hope of producing a favourable progeny. As conventional breeding involves the random transfer of thousands of genes, outcomes are difficult to predict and may take several breeding cycles to refine. Traditional breeding also relies on genetic compatibility between the two organisms to 'cross breed', whereas GM is a precise method that identifies and isolates desired traits within or between species, and then introduces these to a host organism.

HOW IS GENETIC MODIFICATION EFFECTED?

GM is effected by inserting (or deleting) genes from one organism into another to change or modify the genes of the host organism. There are two defined types of genetic modification: *Cisgenesis* artificially transfers genes between organisms that could be conventionally bred, whilst *transgenesis* entails genes from different species being inserted via horizontal gene transfer. In nature, the latter can occur when DNA penetrates the cell membrane for any reason. GM modifies the host organism by physically inserting the extra DNA into the host using a micro-syringe or as a coating fired from a gene gun.

WHAT ARE THE MOST COMMON CROP TYPES AND USES FOR GENETIC MODIFICATION?

First generation genetically modified crops were either insect-resistant (Bt crops) or herbicide-tolerant (HT) strains with the aim of making pest and weed control easier.

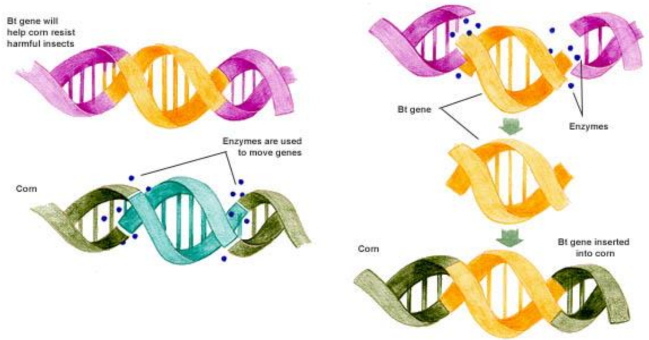

Figure 1. Inserting a BT gene into corn DNA using enzymes results in an insect resistant corn that can reduce pesticide use.

The main crop species in which GM traits have been introduced are maize (corn), soya, cotton and Canola (oil seed rape) which represent around 99% of all GM crops grown. Sugar beet, alfalfa, papaya, squash and eggplant accounts for the remaining 1% and are defined as 'minor GM crops'.[1] Second generation GM crops are being developed with traits that are drought and disease tolerant, or that have enhanced nutritional properties (e.g. golden rice), but these have not, so far, been widely commercialised.

HAVE GM CROPS OVERTAKEN CONVENTIONAL CROPS?

Since commercialisation in 1996, the amount of land given over to GM cultivation has grown exponentially. GM Crops are grown by approximately 17m farmers in 24 countries.[2] Since 1996, the planting of GM crops has grown from 1.7m hectares to 189.8m hectares in 2017.[3] GM therefore represents the fastest adopted crop technology in recent times and not least in the developing world where it is grown in 19 countries (79% of the total). These regions were responsible for over half (53%) of all GM crops grown globally. Bangladesh planted GM crops for the first time in 2014, whilst Indonesia and Vietnam approved biotech crops for cultivation in 2015. Myanmar grew over 323,000 hectares of insect resistant cotton in 2016.[4]

WHERE ARE GM CROPS MOST COMMONLY GROWN?

The United States commits the most land to GM crops with 75m hectares planted (40% of total GM hectares cultivated) in 2017. Brazil is ranked second (50.2m hectares or 26%).

These two markets are followed by Argentina (23.6m hectares), Canada (13.1m hectares) and India (11.4m hectares). Of the 24 countries where GM crops are grown, 13 are classed as biotech mega countries where more than 50,000 hectares are under cultivation.[5] 77% of all soybean and 80% of all cotton grown globally is now biotech. Just under half (49%) of the global planting committed to the four main biotech crops is now GM.[6]

WHAT IS THE POSITION IN EUROPE?

The EU remains the largest territorial block resistant to widespread GM cultivation. Under EU legislation, GMOs can only be released into the environment if a science-based risk assessment has shown no safety compromise. Individual member states can impose a 'safeguard clause' that effectively blocks and prohibits the use of GM products within its jurisdiction. France and Germany are the main opponents of GM in Europe, whilst four other countries have effectively imposed 'safeguard clauses' on their cultivation (Austria, Greece, Hungary and Luxembourg). Since 1992, the EU has approved 2,404 experimental GM field trials, compared to over 18,000 in the USA.[7]

Just two crops have been approved for commercial cultivation in the EU; insect-resistant maize and a potato with modified starch content for industrial-chemical use. Spain is the largest cultivator of GM crops in the EU, with 100,000 hectares under cultivation.[8] Smaller amounts are cultivated in Portugal. More than half of the member states of the EU have effectively 'banned' the cultivation of GM crops under rules introduced in April 2015 that allowed member states to self-decide.

DOES THAT MEAN THAT GM IS LEGALLY ACCEPTABLE IN THE UK?

The UK has not imposed a 'safeguard clause', but there are no commercial crops being grown or licensed in the UK (the two crops licensed in the EU are not suitable for UK cultivation). The UK Government remains committed to good science, recognising that GM technology could deliver benefits providing it is safely deployed. The UK has been among the leading EU voices for 'proportionate' regulation, and supports pragmatic measures to segregate GM crops from conventional and organic crops. However, within the devolved administrations, only England (through the UK Government) has expressed a positive view of GM; Wales, Scotland and Northern Ireland all oppose GM cultivation. Imported GM material, mostly soya, is allowed, principally in animal feed, but also in some food products.

DOES THAT MAKE THE CULTIVATING OF GM CROPS MORE LIKELY?

Not necessarily, as the only GM strain currently licensed for release are not suitable for growing in the UK. There appears to be little appetite at the wider EU level to license more genetically modified strains, and in the UK the number of field trials have reduced considerably from their peak. Recent field trials have included GM wheat, potatoes and 'false flax' which accumulates high levels of Omega 3 oil and could be used as feed in factory fish farming as a health supplement. Most of the field trials are conducted by Rothamstead Research, an independent charitable company and the oldest arable crop research institute in the world.

WHAT ABOUT ANIMAL MODIFICATION – IS THAT ALSO A REALITY?

Animals can be modified in the same way as plants through the introduction of genes intra species or between species. It is subject to the same overarching regulation as crops. Whilst the risk of gene escape is very low, the modification of animals raises complex ethical issues and remains controversial, especially if cloning is the result. Genetically modified mice are widely used in scientific research, whilst livestock can potentially be modified to enhance yield or alter their products. Mongolian scientists have modified cattle to produce healthier milk for those who are lactose intolerant, whilst Chinese scientists successfully introduced human genes into 300 dairy cows to produce milk more consistent with human breast milk. These developments remain controversial. Other examples include the Roslin Institute modifying chickens to resist bird flu, provide a potential treatment for liver damage and weaning birds off antibiotics, and sheep modified to produce a drug capable of treating cystic fibrosis. The first GM animal to be licensed for human consumption was approved by the US

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FDA (Food & Drug Administration) in November 2015 for a salmon containing growth hormone genes taken from two other species to accelerate the salmon's growth. Oxitec, a UK company is pioneering the modification of insects to help control or eradicate diseases such as Dengue Fever.

Figure 2. The piglet on the left was injected with a jelly fish gene that allows it to become fluorescent. This kind of science remains controversial.

ARE THERE ANY DEVELOPMENTS IN GENE TECHNOLOGY?

Genome editing is attracting considerable attention. Gene editing differs from genetic modification in that it does not require inserting a gene into an organism, but 'editing' an existing gene to change its properties. By switching off individual genes, for instance in barley, scientists believe they can develop a strain that will make its own nitrogen fertilisers. Other work includes gene-editing beetroot to produce L-Dopa, a drug used in the treatment of Parkinson's disease. L-Dopa is produced naturally in beetroot, but other genes turn this compound into dyes that make the beetroot purple. Turning off those pathways would allow L-Dopa to accumulate and be a source of medicine, particularly in poorer countries. The European Commission is set to decide whether gene editing should be considered to be GM, and therefore covered by current GM regulations; a ruling by the European Court of Justice in 2018 upheld the long-standing status quo that gene editing is subject to the 2001 Directive banning GMOs.[9] Scientists who argue that gene editing is just accelerated natural breeding, warn of the potential loss in therapeutic benefits if the research becomes subject to restrictive GM regulation. Detractors however argue that gene editing carries the same potential for unforeseeable disruption of the genome as genetic modification such that intervening in that genome may lead to unpredictable outcomes.

WHAT ARE THE BENEFITS CITED FOR GENETIC MODIFICATION?

Proponents of GM cite a range of benefits. If crops can be made more resistant to pests, crop failure can be mitigated. Similar benefits accrue from crops becoming drought, frost and heat resistant. If world population continues to grow to a projected 9bn by 2050, crop yields will need to increase in order to respond to human demand. More food could, as a consequence, be produced from less land if existing land banks yield more. Equally, marginal land previously viewed as unproductive could potentially be brought into use as a result of hardier, saline tolerant crops being cultivated in contaminated saline conditions. One environmental positive often stressed is reduced pesticide use (as plants become pest resistant), which in turn could enable biodiversity to flourish having been in some cases all but extinguished by the use of chemicals. New generation technologies hold out the prospect of vaccine and medicine development, enhanced nutritional properties, the removal of allergens and 'fingerprinting' animal and plant diseases with a view to their genetic elimination.

WHAT ARE THE DRAWBACKS?

GM opponents cite ethical and environmental objections to an 'unnatural' science. The science remains widely mistrusted in the UK and Europe, partly on the back of agricultural scandals such as BSE, and scepticism surrounding artificial manipulation of nature. Ethical concerns therefore tend to centre on human intervention to produce 'unnatural' outcomes such as mixed gene organisms. Cloning or the exact replication of an individual organism via genetic intervention tends to excite most opposition, as does the genetic manipulation of animals where there may be long-term health and welfare issues. Arguments used against GM centre on the long-term unknown consequences of contamination via 'gene escape' and the hypothetical mutation of genes once inserted into an organism. The long-term stability of the host organism is often questioned for which proven scientific evidence is at present absent. GMOs could theoretically breed with wild and natural species, contaminate non-GM or organic crops and create hybrid plants as an unintended consequence. In the UK, with its integrated field system and hedgerows this has been a pertinent concern, with government regulating separation margins between crops. Biodiversity risk is also put forward as a potential downside given there is little field analysis on the impact of horizontal gene flow of GM pollen to bees and other species. The proprietary rights of biotechnology and its accretion by a small number of large corporations may lead to a lack of choice on the part of farmers and consumers. Terminator technologies have caused wide consternation as they would, if applied, prevent a crop from being grown the following year from its own seed; a terminator gene effectively 'switching off' the plant's ability to self-germinate.

WHAT ARE THE ISSUES FOR RESPONSIBLE INVESTORS?

We support responsible, evidence based scientific research where results are published and are subject to independent peer review. To that end, we support government led field trials that aim to understand the risks and opportunities from commercialising GM in the UK. The world faces serious impending food shortages for a combination of reasons, including population growth. Under this scenario, GM may afford an attractive solution if modified pest resistant crops can be made to grow in challenging or marginal climates. In the UK and Europe, segregation is going to become increasingly problematic as GM harvested crops increase in volume - 82% of all soy planted and which is a staple in animal feed is now GM – so that keeping it out of the human food chain may, ultimately, be impossible. As responsible investors we look to the scientific community for leadership; the Nuffield Council on Bio-ethics noted that "*all forms of plant breeding have directly and indirectly changed individual crops or biodiversity. Risks and benefits of specific interventions need to be considered in individual cases. We do not think that arguments about 'naturalness' are convincing enough to rule out the responsible exploration of the potential of GM*." The Council also supports gene flow assessment on a case by case basis as far as environmental risk is concerned: "*Gene flow occurs widely throughout nature. Whether or not it is acceptable depends primarily on its consequences. The possible risk would depend largely on the particular crop and trait*." Crops that readily cross pollinate will require stronger margins for control than those that cannot, such as wheat. GM companies have a role to play in fostering consumer and public confidence in the science, and ultimately in GM itself. They should conduct their research in accordance with sound science and with ethical rigour, whilst meeting all legal and regulatory requirements, and providing farmers with choice.

The modification of animals remains largely experimental and research based at present. However, this area of research remains highly controversial, and a justifiable medical or pharmacological imperative would seem to be a minimum requirement if companies are to enter this field more widely and for commercial advantage. We would expect to review any such proposals with caution and on a case by case basis.

Notes

1-6 International Service for the Acquisition of Agri-biotech Applications
http://www.isaaa.org/resources/publications/pocketk/16/

7 Royal Society www.royalsociety.org

8 ISAAA ibid

9 www.sciencebusiness.net

EDENTREE RI EXPERT BRIEFING | SEPTEMBER 2019

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