Genetic Engineering in Agriculture

Has it fulfilled its promise?

As the UK prepares to leave the EU, there has been a great deal of discussion around breaking with the strict regulatory approach of the EU and pursue an independent line of regulation for genetically engineered crops. However, public acceptability of these technologies is uncertain and their unregulated use would also have implications for exporting commodities and food products into the EU and other markets.

With an eye on technology driven exports, some might argue that the risk of alienating some consumers and markets is worth it. But what evidence is there that first generation GM crops have brought benefit and/or market gains; and what proof is there that gene or genome edited crops – produced by any one of a suite of new genetic engineering (GE) technologies will do any better? Importantly, how do they stack up against ongoing innovation and success in conventional breeding?

In the 25 years since the introduction of GM crops…

Pesticide use has gone up A 2012 study out of Washington State University[1] found GM crops quickly encouraged herbicide resistant 'superweeds' and, as a result, increased herbicide use. By 2016 research was demonstrating that glyphosate-resistant weeds had led to a 28% hike in herbicide use on GM soybeans compared with non-GM.[2] This rise has also been reported in other countries such as Canada,[3] Brazil[4] and Argentina.[5] In 2017 insects had begun to show resistance to the insecticides bred into GM plants[6] causing farmers to use more, and more dangerous mixtures, of other pesticides to try and control them.

There has been no improvement in yields attributable to GMOs US government data shows yields from GM crops can be lower than their non-GM equivalents.[7] In 2016 an in depth analysis by the *New York Times*,[8] based on United Nations data, concluded that genetic modification in the US and Canada has failed to bring the expected increases in crop yields. That same year a National Academy of Sciences report found that "there was little evidence" that the introduction of genetically modified crops in the US had led to yield gains beyond those seen in conventional crops.[9]

Seed prices have gone up Adoption of genetically engineered crops has corresponded with increasing monopolisation of seed by biotechnology companies and higher seed costs. In competitive markets. According to the USDA's Economic Research Service, between 1995 and 2011, the cost of purchasing seed to plant one acre of soybeans and corn increased 325% and 259%,

[1] https://enveurope.springeropen.com/articles/10.1186/2190-4715-24-24
[2] https://advances.sciencemag.org/content/2/8/e1600850
[3] https://www.ourcommons.ca/Content/Committee/421/AGRI/Brief/BR8451190/br-external/CanadianBiotechnologyActionNetwork-e.pdf
[4] http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1413-81232017021003333
[5] https://www.grain.org/article/entries/706-twelve-years-of-gm-soya-in-argentina-a-disaster-for-people-and-the-environment
[6] https://www.nature.com/articles/nbt.3974
[7] http://www.ers.usda.gov/publications/err-economic-research-report/err162.aspx#.U7vzi7Hrzbx
[8] https://www.nytimes.com/2016/10/30/business/gmo-promise-falls-short.html
[9] https://www.nap.edu/catalog/23395/genetically-engineered-crops-experiences-and-prospects

respectively, while yield per acre only increased 18.9% and 29.7%, respectively.[10] This is roughly the time period when acreage of GM corn and soy grew from less than 20% to more than 80-90%.

No consistent increase in profit for GMO farmers US government research[11] shows that while the cost of growing these crops has spiralled, the profitability of GM crops is highly variable. The high cost of seeds combined with increased chemical inputs they require, means GM crops have proved more costly to grow than conventional crops.

GMO crops are not feeding the world Around 40% of GM crops are turned into biofuels, the rest are used as ingredients – mostly oils and sugars from corn, soya and cottonseed – for unhealthy highly processed human food, or used as animal feed. In the years since the introduction of GM crops world hunger has not been beaten. While some countries struggle to feed their citizens, others consume far too many calories but not nearly enough nutrients. This phenomenon, known as mal-consumption, now joins under- and over-consumption as a global health problem.

Conventional breeding is delivering

What has conventional plant breeding (including genome mapping techniques and masker assisted selection) achieved? GMO plant breeding receives considerable media and political attention, usually around its claimed potential benefits. In fact, little of this potential has actually been realised in the shape of varieties that are proven and have a commercial value.

Meanwhile, conventional (non-GM) plant breeding has built up an impressive track record in producing crops through research and development to in-field and commercial use. An inventory of conventional plant breeding spanning 2004-2020[12] lists a large number of crops and varieties which both potentially and actually deliver an array of benefits including, increased/optimised yields, disease resistance, drought resistance, flood resistance, salt tolerance and nutritional enhancement for a range of crops (cereals, maize, rice, tomatoes, potatoes, legumes, fruits) which are important for the developing and the developed world.

Conventional breeding uses genomic technologies The introduction of genome mapping, sequencing and marker assisted selection has revolutionised conventional plant breeding in the last 10-15 years. Plant breeders have used these tools and not GE to reduce the time and increase the precision of trait selection. So much so that GMOs, as typified by transgenesis (transferring genes), has, in many cases, been seen as unnecessary in the breeding process (as opposed to the political and funding process), or has been superseded by conventional breeding in terms of speed, reliability and quality outcomes.

Why hasn't GMO breeding delivered? The plant breeding and seed industry globally is highly concentrated. A 2016 report from the UK government Intellectual Property Office[13] noted that just 7 companies (6 since Monsanto/Bayer merger) control 71% of the global seed market. These same companies also dominate in agrichemicals (pesticides, herbicides, fungicides). Their plant breeding focus has therefore been on maximising profits across the supply chain for large scale commodity crops (maize, soy beans, oils seed, cotton) which use their agrichemical inputs.

For the most part they have not been interested in applying their GMO technology to, for example, draught resistance in sub-Saharan Africa because:

[10] https://downloads.usda.library.cornell.edu/usda-esmis/files/j098zb09z/7w62fb474/zw12z7657/Acre-06-28-1996.pdf; See also https://downloads.usda.library.cornell.edu/usda-esmis/files/j098zb09z/6395w898j/db78tf232/Acre-06-29-2012.pdf.
[11] http://www.ers.usda.gov/publications/err-economic-research-report/err162.aspx#.U0P_qMfc26x
[12] https://www.gmwatch.org/en/non-gm-index
[13] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/552498/Plant-breeders.pdf

- They don't own the varieties and traits that do well in those conditions and would not sell enough seeds or agrichemicals to make it worthwhile; and

- Breeding from wild and/or indigenous plant material to introduce or enhance traits (e.g. drought tolerance) is a much more complex process than breeding from existing conventional monocrops, involving more gene constructs and interactions and time.

This is why most R&D into characteristics such as draught have been carried out with international aid and philanthropic funding in public or charitable institutions. New genome mapping and selection has made this breeding easier but these non-commodity crops are a commercial disincentive for plant breeders looking for big market wins.

Public and market resistance still dominates the politics of genetic engineering

Consumers reject GE foods The majority of the British public remain opposed to genetically engineered crops and foods. The 2017 poll for Bright Blue, which looked at opinions around a green Brexit, across the political spectrum, found that 61% of Conservative voters polled wanted a ban on the production of GM crops[14]. Looked at through the lens of 'leavers' and 'remainers' the survey also found that a similar percentage, on both sides, favoured maintaining or strengthening regulations around GM crops.

Nearly 5000 people have signed the joint petition by Beyond GM and GM Freeze to keep GM labelling post-Brexit.[15] Nearly 2400 UK citizens have taken the time to add their photos and comments to the GM Free Me visual petition,[16] which provides rolling insights into how people from across the social spectrum feel about genetically engineered products in the UK food supply.

Of relevance to our trading relationship with the EU, European consumer group, BEUC surveyed 11,000 consumers in 2019[17] and found amongst other things that consumers most spontaneously associate "sustainable food" with "low environmental impact" (48.6%), "use of GMOs and pesticides to be avoided" (42.6%) and "local supply chains" (34.4%).

Supermarkets are wary and will follow the public The experience in European countries suggests that supermarkets will continue to go where customers lead on GMOs. Leading retailers such as Aldi, Carrefour, EDEKA, Kaufland, Lidl, Rewe and SPAR have been following a strict non-GMO policy for many years. Consumers do not want to eat GMOs, retailers do not want to sell them.

Here in the UK, GMOs have not had such a high public profile in recent years but nonetheless supermarkets have largely been wary of changing their previously stated commitments to a GM free supply chain. The recent upsurge of publicity for genome editing has led to several of them to approach anti-GM groups for information and advice.

There are also active discussions with the Non-GMO Project verification scheme[18] in the US about bringing this certification to the UK should deregulation become a reality. The continued growth in organic food sales growth across all sectors in the UK is, in part seen as recognition of the attraction of avoiding GMOs.

[14] https://brightblue.org.uk/wp-content/uploads/2017/04/Green-conservatives-polling-report-Final.pdf
[15] https://beyond-gm.org/joint-petition-demands-the-uk-protect-gm-food-labels-post-brexit/
[16] https://www.gmfreeme.org/
[17] http://www.beuc.eu/publications/beuc-x-2020-042_consumers_and_the_transition_to_sustainable_food.pdf
[18] https://www.nongmoproject.org/product-verification/

Genome editing innovators advising caution is a strong political message To date genome editing has had a favourable press but little to show in the marketplace. There is only one genome edited crop approved for the market – the Calyxt GE soybean[19] – being sold into the US fast food market.

In the meantime, an increasing number of geneticists are calling for caution and the need for some form of regulation, transparency and labelling will gain significant traction. This message will resonate powerfully with those members of the public who may be somewhat sympathetic to the perceived potential of genome editing but are cautious and want farmers and consumers to have open and transparent choice.

Prof Kevin Esvelt of MIT, developer of the gene drive, believes that early and irresponsible promotion of the technique means: "*We are walking forwards blind. We are opening boxes without thinking about consequences. We are going to fall off the tightrope and lose the trust of the public*."[20]

Co-inventor of CRISPR-Cas9 genome editing technology, Jennifer Doudna, believes there is an "*urgent need for open discussion of the merits and risks of human genome modification*".[21] These same errors which Doudna sees in human gene editing can also occur in 'edited' plants and animals. George Church, at Harvard University, who also helped develop CRISPR/Cas-9, suggests that, given the level unwanted – and even dangerous – mutations it creates, 'genome vandalism' is a more accurate description than 'genome editing'.[22]

When a 2020 study by the US Food and Drug Administration (FDA)[23] revealed that an experimental gene-edited cow – claimed by its producers to be 100% beef – contained a sequence of antibiotic-resistant bacterial DNA in its genome, Dr Belinda Martineau, developer of the Flavr Savr tomato, noted that the developers had the tools to find mistakes like these for themselves, but in the rush to market incompetently failed to use them. "*Such big mistakes made during the development of these 'poster children' GMOs make one wonder how carefully other, more run-of-the-mill GMOs have been developed over the last 25 years as well.*"

She added that the developers of golden rice had also failed to avoid unintended mutational errors attributable to the genetic engineering process itself, saying: "*Scientists still have a lot to learn about unintended consequences associated with all methods currently used to genetically engineer organisms, especially newer methods like gene-editing.*"[24]

In a frank editorial[25] accompanying the study FDA noted: "*At this early stage, as genome-editing technology is continuing to develop and the science is evolving, bringing products with unknown risks to market without adequate oversight to ensure they are safe and that they produce the promised effects will undermine consumer confidence and, ultimately, set back the progress of the entire field.*"

[19] https://www.the-scientist.com/news-opinion/gene-edited-soybean-oil-makes-restaurant-debut-65590
[20] https://splinternews.com/this-scientist-is-trying-to-stop-a-lab-created-global-d-1793857858
[21] https://news.berkeley.edu/2015/03/19/scientists-urge-caution-in-using-new-crispr-technology-to-treat-human-genetic-disease See also https://science.sciencemag.org/content/348/6230/36.full
[22] https://www.sciencemag.org/news/2019/10/new-prime-genome-editor-could-surpass-crispr
[23] https://www.nature.com/articles/s41587-019-0394-6
[24] https://biotechsalon.com/2020/02/17/in-light-of-big-mistakes-made-by-developers-of-poster-child-gmo-products-like-hornless-cattle-and-golden-rice-fda-is-justified-in-requiring-regulation/
[25] https://www.nature.com/articles/s41587-020-0413-7