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Cultivating the Future:

How can 20 years of GM debate inform UK farm policy?

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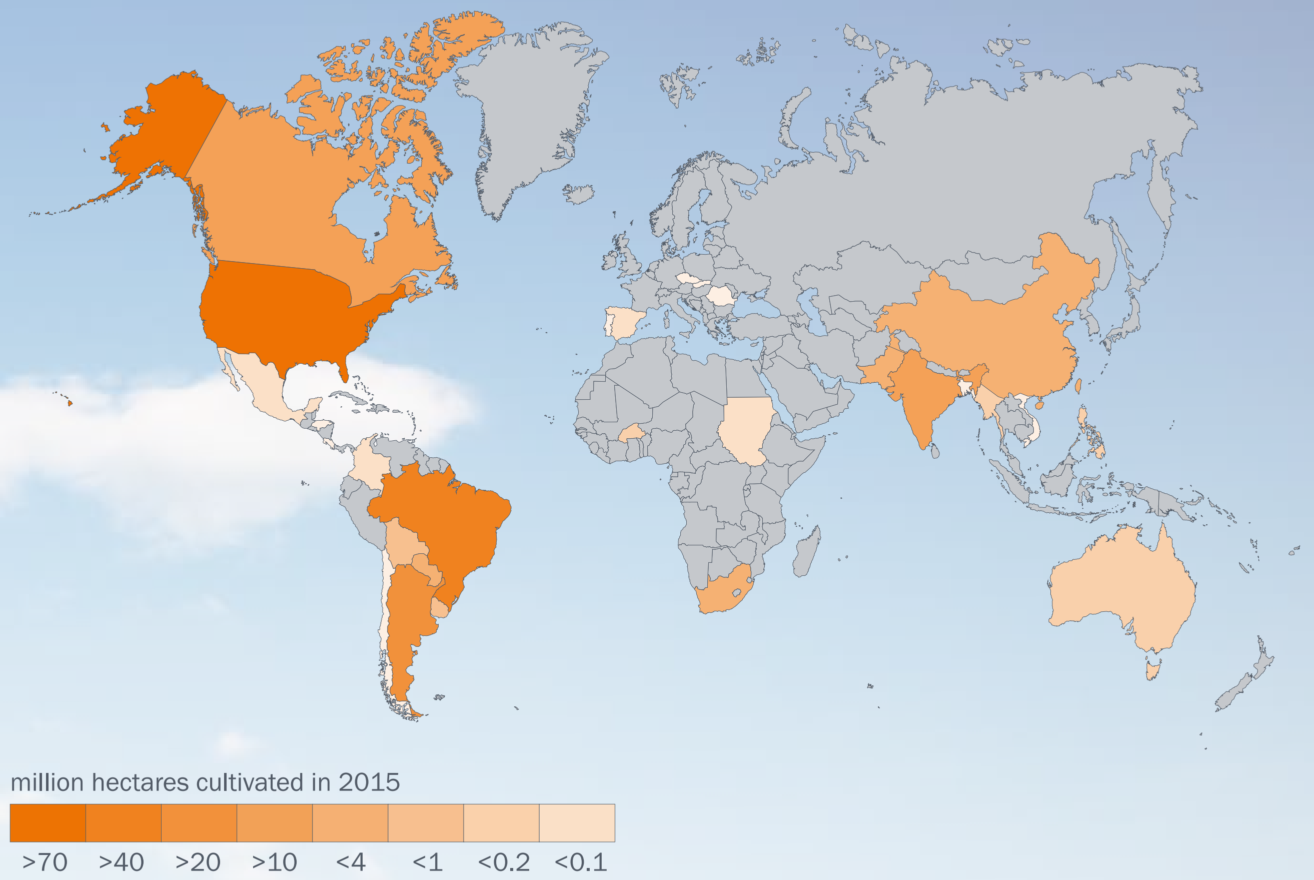
18million farmers from 28 countries cultivated 180 million hectares of biotech crops in 2015



Rank	Country	2015
1	USA	70.9
2	Brazil	44.2
3	Argentina	24.5
4	India	11.6
5	Canada	11.0
6	China	3.7
7	Paraguay	3.6
8	Pakistan	2.9
9	South Africa	2.3
10	Uruguay	1.4
11	Bolivia	1.1
12	Philippines	0.7
13	Australia	0.7
14	Burkina Faso	0.4

Rank	Country	2015
15	Myanmar	0.3
16	Mexico	0.1
17	Spain	0.1
18	Colombia	0.1
19	Sudan	0.1
20	Honduras	<0.1
21	Chile	<0.1
22	Portugal	<0.1
23	Vietnam	<0.1
24	Czech Republic	<0.1
25	Slovakia	<0.1
26	Costa Rica	<0.1
27	Bangladesh	<0.1
28	Romania	<0.1

Foreword

Agricultural Biotechnology Council

Food security is one of the greatest challenges facing the world in the first half of the 21st century. The next 20 to 30 years will see rapid population growth and the increasing impact of climate change on agriculture. The United Nations Food and Agriculture Organisation has projected that farmers will need to produce 70 percent more food by 2050 to meet the needs of a global population which, by that time, will have grown to over 9 billion people.

This presents an enormous challenge for the agricultural sector and farmers globally. Presented with this challenge farming must adapt; to become more productive, more resilient to plant and animal disease and better at protecting the natural environment. To achieve this it is essential that farmers are able to use all the tools and technologies available to them.

2016 marks the 20th anniversary of the first commercial cultivation of genetically modified (GM) crops. GM crops are just one of the many technologies that have been developed to increase agricultural yields, and will need to be part of the solution to the challenge facing agriculture in the coming years. To mark the anniversary, this collection of essays looks back at the impact of this technology on farming over the last 20 years.

As the essays demonstrate, the last 20 years have seen exciting breakthroughs in plant technology and pioneering new approaches to food and farming systems. These advances have seen an increase in global crop production, as well as a significant reduction in the environmental impact of herbicides and pesticides. The collection also considers some of the challenges faced by GM over this period and how best to ensure that, going forwards, the technology can be utilised alongside other farming techniques to ensure the benefits are enjoyed by farmers and consumers.

The essays in this collection have been written by a range of experts from across the agri-food sector, and it includes the viewpoints of prominent academics, farmers in the UK and abroad, and the food manufacturing industry among others. Bringing together this range of contributors provides a fascinating insight into the challenge facing agriculture, how technology is already meeting that challenge, and the importance of ensuring technology is fully available to achieve the levels of cultivation needed in the future.

We hope that this collection will challenge readers and begin to address how we can meet the future challenge of feeding a growing population whilst protecting our natural environment.

Comprising six member companies, abc works with the food chain and research community to invest in a broad range of crop technologies, including conventional and advanced breeding techniques, such as GM. These are designed to improve agricultural productivity by tackling challenges such as pests, diseases and changing climatic conditions, while reducing water usage, greenhouse gas emissions and other inputs. The companies are BASF, Bayer, Dow AgroSciences, Monsanto, Pioneer (DuPont) and Syngenta. Further information is available at www.abcinformation.org

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What are the challenges and what has been the role of biotechnology over the last 20 years?

Future challenges and the need for innovation

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The development of genetic technology was one of the great human achievements of the 20th Century. From the first discovery of DNA in the 1930s it took 40 years for scientists to create the first recombinant DNA. Subsequently it was another 25 years to the first commercial genetically modified crop planting in 1996. Now, 18m farmers from 28 countries cultivate 180m hectares of biotech crops[1]. Genetic biotechnology has seen one of the fastest rates of uptake of any new technology in the world: genetically modified crops make up 12% of global arable land[2]. There are more than a few unknowns about the 21st Century, but the rate of scientific development and innovation using biotechnology will surely only increase.

The Challenge

There are a few other mega-trends that lend some certainty about what the early part of the 21st Century will look like. Firstly, demographic momentum means that there will be over a billion extra people by 2030, bringing the global total to over 8bn[3]. Secondly, urbanisation trends will continue globally, so that the global urban:rural ratio is forecast to be ~57% by 2030[4]. Thirdly, global prosperity levels are likely to continue to improve, with forecasters predicting an expansion of the global middle class by 165% by 2030, adding over 3bn households with daily incomes of between $10 and $100. Fourthly, and most importantly, greenhouse gases in the atmosphere *now* are going to drive climatic changes up to 2030. That is the case whatever the reduction in emissions in the immediate future and despite encouraging signs from Paris.

Demography, urbanisation and growing prosperity lead us to a triumvirate of challenges in the form of food, water and energy needs, all set in a context of a dramatically changing climate. Energy demand is expected to increase by 55% by 2030[5]; water demand by 60%[6]; and world agricultural production by 40%[7]. World level increases in food demand, generally, are 70% determined by population growth and 30% by per capita income growth[8]. To meet projected crop needs without land use change, average yields need to grow 15% *more* than they did during the Green Revolution period in the last half of the 20th Century, when selective breeding led to doubling of yields of rice and wheat in Asia[9].

There is a growing focus on future food system challenges, and increasing recognition of the central role that needs to be played by nutrition requirements. Malnutrition takes many forms. Out of a current world population of 7 billion, around 2 billion suffer from micronutrient malnutrition, and nearly 800m people suffer from calorie deficiency. Out of 5 billion adults worldwide, nearly 2 billion are overweight or obese, and 1 in 12 has type 2 diabetes. Out of 667m children under age 5 worldwide, 159m are stunted, 50m are wasted, and another 41m are overweight[10]. The 2016 Global Nutrition Report[11] found that out of 129 countries with data, 57 have serious levels of *both* undernutrition and adult overweight/obesity issues. These are complex, wicked problems.

Developing countries will be the epicentre of the 21st Century storm. More than half of global population growth between now and 2050 is expected to occur in Africa. The increase in city-dwellers is 90% concentrated in Asia and Africa[12]. And it is exactly these countries that face the greatest risk from climate change. There is a growing body of evidence that links human influence on climate with increasing risks of certain types of extremes[13], notably heatwaves (for instance, the Chinese spring of 2014), floods (for instance, the UK winter of 2013) and hurricanes (for instance, the Hawaiian hurricane season of 2014). The top 10 countries in the Germanwatch Climate Risk Index, which ranks countries according to their extreme weather risks, are developing countries (led by Bangladesh, Myanmar and Honduras). 95% of fatalities from natural disasters in the last 25 years occurred in developing countries[14].

> "to meet projected crop needs without land use change, average yields need to grow 15% more than they did during the *Green Revolution* period in the last half of the 20th Century, when selective breeding led to doubling of yields of rice and wheat in Asia"

Let us compare these figures with those available regarding the use of genetic technologies. Since 2012, developing countries have planted more biotech crops than developed countries. In 2015 farmers from Latin America, Asia and Africa collectively grew 97.1m hectares, or 54% of the global total. But that is heavily skewed towards Latin America: Asia accounted for only 19.5m hectares, and Africa for only 3.3m hectares. Only three African countries (South Africa, Burkina Faso and Sudan) currently grow biotech crops[15].

The role of biotechnology in meeting the challenge

Biotechnology is one of the most powerful tools currently available to us. In order to deploy these tools, we also need the political will to adhere to policies which are evidence-based – often this is not a popular path to take. An unfortunate consequence of the 20th Century is the political reaction to poor practices such as under-regulated chemical use, corporate misbehaviour and negative PR. A 'suspicious summer' has followed Carson's 'silent spring'. Those participating in modern agriculture, and those implementing regulations surrounding it, need to deal fairly with this inherent mistrust. As President Obama noted, "Promoting science is about protecting free and open enquiry. It is about listening to what scientists tell us, even when it's inconvenient – especially when it's inconvenient". It is also about understanding the alternatives: for instance, it is not fully understood that without access to GM technology, the only alternative is a radical increase in the use of fertilisers, insecticides and herbicides to boost yields. In 2014 the estimated reduction in the amount of pesticide use thanks to biotech crop use was 584m kg.

If genetic modification was the biggest biotech development of the 20th Century, gene-editing is surely its successor in the 21st. This technique allows scientists to rapidly, cheaply and accurate 'search-and-replace' stretches of DNA, making targeted gene manipulation dramatically easier. The range of potential applications in agri-technology is tremendous, not just concerning classic questions of yield improvement or pest resistance, but also (for instance) in crop wastage or food safety. Gene editing is also a powerful basic tool that is likely to aid our understanding of how plant genomes work, and how to work with species like bananas, cassava, plantain and potatoes, that are very difficult to improve using conventional breeding methods.

Gene-edited crops offer significant advantages over conventional GM crops. Gene editing is more precise than conventional GM, and alters less genetic material. Once gene editing has been performed in transgenic plants, the transgenic part can be easily separated from the edited target via a traditional cross or self-pollination, resulting in a plant that contains no foreign DNA.

There is an encouraging movement towards the idea of regulating new crop varieties based on the characteristics of a novel crop, not on the techniques used in its synthesis. This approach is already used in Canada. This makes far more scientific sense because in many cases it is impossible to tell what method was used to produce a new crop variety. As noted by the BBSRC in its recent position statement, “the boundaries between established GM techniques and non GM techniques will become increasingly blurred as techniques develop”[17].

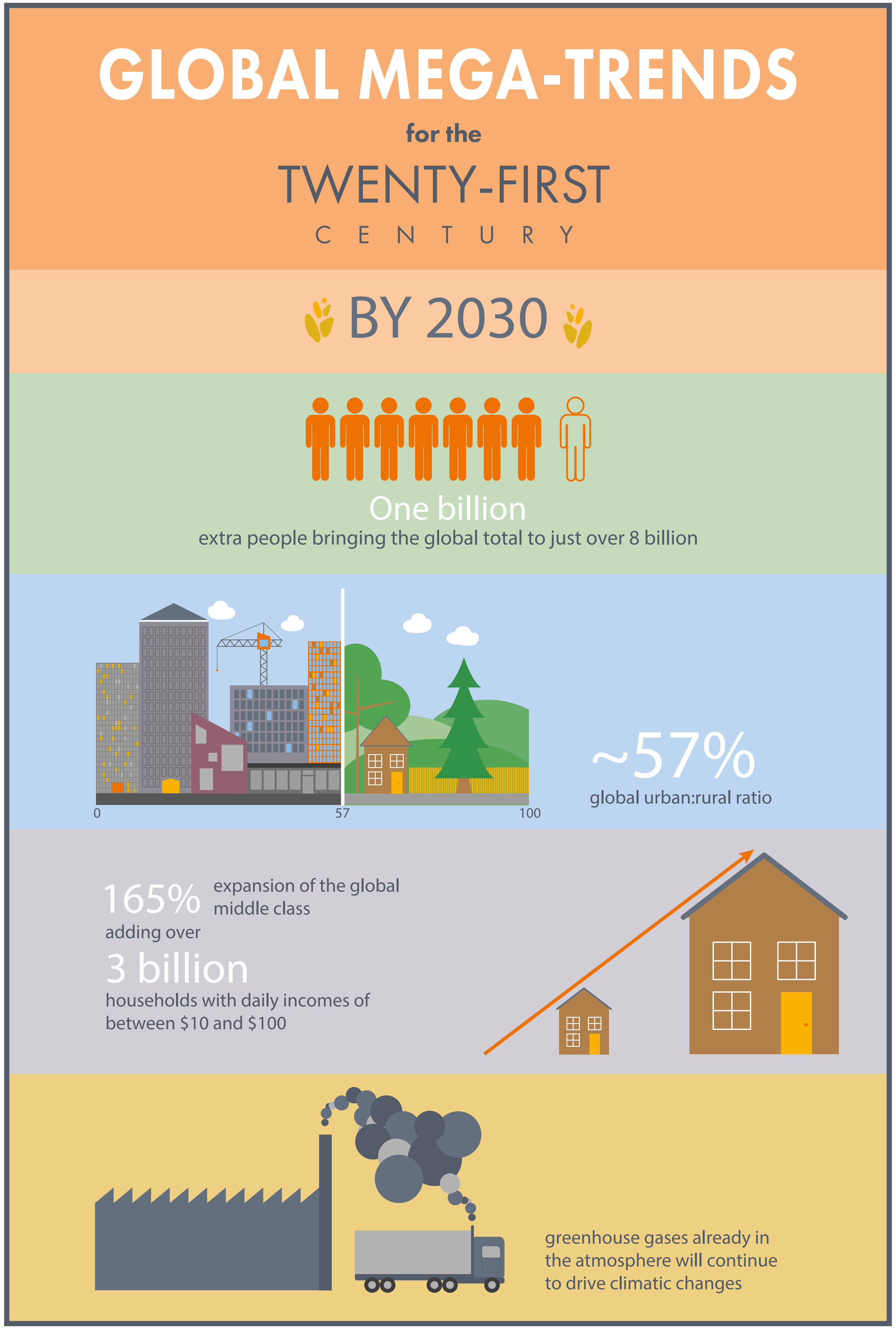
Taking a parochial view, the UK biotechnology industry is characterised by advanced science and important innovation, but in practical terms this has resulted in no tangible benefits to the UK farmer, as no products have been licensed to be used in the UK. Indeed, with the exception of maize in Spain, this is largely the case for the EU as a whole, which grew only 0.117m hectares of GM crops in 2015[18]. Whether the situation continues post-Brexit will obviously depend on detailed discussions on the future trade of the UK with Europe.

Decision-makers as well as scientists need to view genetic technologies as an essential part of a broad suite of tools available to tackle the complex challenges of the future. Our approach needs to be holistic and multi-disciplinary. For instance, we need innovative ways to think about food and farming in an urbanised world, for example using vertical farms and tailored peri-urban agriculture. We also need to think about the future of world agriculture in terms of how biotechnology fits into sustainable, small-farm agriculture – not only because this is the sort of agriculture found in developing countries, but also because it is more supportive of a biodiverse environment.

A rapid rate of uptake of a scientific breakthrough can be no less than detrimental if it results in low public acceptance of the technology. Agricultural scientists have learnt that lesson with GM. But we must embrace the increasing velocity of technological developments as not only good, but essential. We are facing unprecedented challenges, and we need a full range of tools, and the sensitivity and intelligence of how to deploy them well.

NOTES

1. ISAAA, 2016
2. UK Council for Science and Technology
3. World Population Prospects, UN 2015
4. World Urbanization Prospects, UN 2014
5. World Energy Outlook, IEA 2015
6. 2030 Water Resources Group, 2013
7. World Agriculture Towards 2030/2050: 2012 Revision, UN
8. World Agriculture Towards 2030/2050: 2012 Revision, UN
9. FAO, 2014
10. All statistics from Global Panel on Agriculture and Food Systems for Nutrition, 2016
11. Global Nutrition Report 2016, IFPRI
12. World Urbanization Prospects, UN 2014
13. E.g. see Stott et al 2004, Hoerling et al 2012, Nuccitelli 2014, Coumou & Rahmstorf 2012, Min et al 2011, Pall et al 2011 and Anderson & Bausch 2006
14. Global Climate Risk Index, Germanwatch 2016
15. ISAAA, 2016
16. New Techniques for Genetic Crop Improvement, BBRSC 2016
17. ISAAA, 2016



What is the view from the British agricultural sector?

Biotechnology and British agriculture: Having technology as part of the picnic

Dr Helen Ferrier
Chief Science and Regulatory
Affairs Adviser, NFU

Producing food is no walk in the park and technology is part of the solution
The NFU has watched the rapid adoption of GM technology in crop production over the last 20 years with great interest, mixed with increasing frustration and sometimes weary acceptance that the UK is being left behind. We represent businesses in all sectors of farming, and as you might expect our members have views along the whole spectrum from passionately opposed to GM, through ambivalence to extremely positive about what biotechnology could offer the UK. The NFU's position has long been that British farmers must have the choice to access the best tools to increase their productivity, resilience and profitability, and to compete in the global marketplace. Biotechnology is one such tool, and when used to breed crops now covering nearly 180 million hectares it has been shown to have clear benefits to farmers, environment, economy and wider society. We are also convinced by the overwhelming independent scientific evidence from around the world that GM food and feed is safe. And we know our farmers can grow crops with different specifications to supply separate markets: Coexistence is a routine part of commercial agriculture.

As with any technology, GM and other biotechnologies will never be silver bullets for British farmers. However, the extent of the challenge to protect our crops from pests, disease and weeds and to deliver the quantity and quality of food demanded year after year is frightening. Advancements in understanding the genetic make-up of not only crop plants and farm animals but also the organisms that attack them could deliver step changes in the efficiency, productivity and sustainability of farming. The solutions are there in the labs of research organisations and seed companies, and in the fields of farmers around the world. So what are we waiting for?

GM is already part of British agriculture
Even though NFU members are not yet growing GM crops in this country, they have been using biotech products to provide high quality protein feed for their animals for nearly 20 years. The extent of the adoption of GM technology across the world means that it has become an established part of the global supply chain, and the UK is firmly and inextricably part of this. The feed chain that enables farmers to put British meat, eggs and dairy products on the shelves in this country relies on imports of protein-rich grains, beans and oilseeds, particularly soya and maize. The majority of these imported feed rations are made from GM ingredients, from crops grown in North and South America, India and China. High-quality vegetable proteins are essential to ensure correct nutrition and maintain animal health and welfare standards. And in Europe we cannot grow all we need.

There is a premium to be paid for non-GM feed. For pig and poultry businesses in particular, feed represents the single biggest proportion of their cost of production. Any increase in feed price, whatever the cause, will have a significant impact on what are already very tight margins. Indeed, in 2013, the inability to reliably source sufficient non-GM soya for poultry rations led to most retailers changing their specifications to enable suppliers to use GM soya. The sourcing difficulties and price differential are not just driven by the market. Unfortunately, the politics at play in the EU affect the regulatory process and this has caused damaging disruption in trade flows between Europe and major exporting countries, in turn pushing up prices for British farmers. It may be that a UK outside of the EU would be able to avoid this long-running dysfunctional system, but the potential for this is not yet clear.

Of course, there is a choice here: The UK could accept the damage to the competitiveness of its own livestock and poultry businesses, and simply fill the gaps on the shelves with imported products. Products made from animals and birds reared overseas using GM feed. But what an ironic and unnecessary position, given the 20 year history and proven safety record of this technology in farming.

The need to protect crops, and animals too
Farmers have looked for ways to protect their crops and animals from pests, diseases and weeds since the birth of agriculture. Chemistry is one important source of answers. There are records of sulphur being used by Sumerian farmers to control insects 4500 years ago, and ever since then both organic and inorganic chemistry has been a vital tool in plant and animal health.[1] Even though research has led to active ingredients and formulations that deliver efficacy, selectivity and safety undreamt of 50 years ago, crop protection products are now rapidly being lost to a European regulatory system that is unscientific, based on hazard rather than risk and driven by an inappropriate interpretation of precaution. As with GM regulation, it remains to be seen if, having left the EU, the UK will be able to improve this picture. In any case, given the undoubted strength the UK has in bioscience and plant genetics, it seems eminently sensible to be looking to the power of biology to help crops look after themselves.

Protecting their crops and livestock remains a formidable and ever-present challenge for all farmers whatever their system. No single approach will cut it. As well as pesticides and veterinary medicines, farmers use knowledge of agronomy and animal husbandry to ensure their hard work produces food of the quality and quantity required. Innovations in farm machinery, precision applications, satellite and sensor technologies, varieties and breeds, biological controls, housing. They are all part of an integrated approach already being used to manage pests and diseases. Farmers see biotechnology as one more source of solutions.

Volatile times
Most farming happens outdoors, and all farmers need both to buy inputs and to sell their products. This exposes them to volatility in the weather and to volatility in prices. Both are factors that are well-nigh impossible for farmers to control or avoid. Exploring ways for businesses to manage and mitigate the impact of volatility and to become more resilient to it is therefore central to the NFU's work. Just as their forefathers needed to embrace new ways of managing risks, 21st century farmers see the adoption of innovative practices and new technologies, including biotechnology, as absolutely essential to securing their future in an uncertain world.

NOTES

1. Unsworth, 2010, "History of Pesticide Use", International Union of Pure and Applied Chemistry http://agrochemicals.iupac.org/index.php?option=com_

Adoption and impact of GM crops: 20 years' experience

Graham Brookes
Agricultural Economist at PG Economics, UK

This essay provides insights into the reasons why many farmers have adopted crop biotechnology and continue to use it in their production systems since the technology first became available on a commercial basis. However, farmers in the UK have not had the opportunity to use this technology.

The information presented draws on the key findings relating to the global impact of genetically modified (GM) crops[1,2] and focuses on the farm level economic impacts and the environmental effects associated with pesticide use and greenhouse gas (GHG) emissions.

Use of crop biotechnology
1996 was the first year in which a significant area of crops containing GM traits were planted on a global basis (1.66 million hectares). Since then there has been a dramatic increase in plantings and in 2015, the global planted area was about 180 million hectares. GM traits have largely been adopted in four main crops - canola[3], maize, cotton and soybeans and in 2015, GM traited seed accounted for almost half of the global plantings to these crops.

Farm level economic impacts
GM technology has had a significant positive impact on the income of farmers who have used the technology. In 2014, the direct farm income benefit from GM crop technology was US$17.7 billion. This is equivalent to having added 7.2% to the value of global production of the four crops and equal to an average increase in income of US $101/hectare. Since 1996, the use of crop biotechnology has increased farm income by US$150.3 billion. This income benefit has been divided almost equally between farmers in developing (51%) and developed (49%) countries.

A primary reason why the technology is popular with farmers can be seen from an investment perspective. The cost farmers paid for accessing crop biotechnology in 2014 ($6.9 billion[4,5] payable to the seed supply chain) was equal to 28% of the total gains (a total of $24.6 billion). Globally, farmers received an average of $3.59 for each dollar invested in GM crop seeds, with farmers in developing countries receiving $4.42 for each dollar invested in GM crop seeds in 2014 (the cost is equal to 23% of total technology gains), while farmers in developed countries received $3.14 for each dollar invested.

These farm income gains have occurred from the following sources:

- Herbicide tolerance (HT) technology. The benefits largely derive from more cost effective (less expensive) and easier weed control for farmers. In some countries, the improved weed control has contributed to higher yields and helped farmers in Argentina grow 'second crop' soybeans after wheat in the same growing season[6].
- Insect resistance (IR) technology. The main benefit from use of this technology has been higher yields from reduced pest damage. The average yield gains over the 1996-2014 period across all users of this technology has been +13.1% for insect resistant corn and +17.3% for insect resistant cotton relative to conventional production systems. 2014 was also the second year IR soybeans were grown commercially in South America, where farmers have seen an average of +9.4% yield improvements.

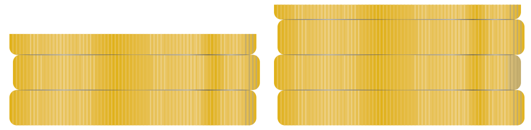
The higher yields and extra production arising from use of crop biotechnology has delivered an additional global production of 158.4 million tonnes of soybeans and 321.8 million tonnes of corn (1996-2014). The technology has also contributed an extra 24.7 million tonnes of cotton lint and 9.2 million tonnes of canola. If this technology had not been available to the (18 million) farmers using the technology in 2014, maintaining global production levels at the 2014 levels would have required additional plantings of 7.5 million ha of soybeans, 8.9 million ha of corn, 3.7 million ha of cotton and 0.6 million ha of canola. This total area requirement is equivalent to a third of the arable land in Brazil.

Environmental impact from changes in insecticide and herbicide use
GM crops have contributed to a significant reduction in the environmental impact associated with insecticide and herbicide use on the areas devoted to these GM crops (Appendix 1). Since 1996, the use of GM technology has directly resulted in insecticide and herbicide use on the global GM crop area falling by 581 million kg of active ingredient (an 8.2% reduction). This is equal to the total amount of pesticide active ingredient applied to crops in China for more than a year[7].

Whilst changes in the volume of pesticides applied to crops can be a useful indicator of environmental impact, it is an imperfect measure because it does not account for differences in the specific pest or weed control programmes used in GM and conventional cropping systems. Using a better measure of the environmental impact associated with pesticide use, the environmental impact quotient (EIQ8), this measure shows that the environmental impact associated with herbicide and insecticide use on the area planted to GM crops between 1996 and 2014 fell by 18.5%. In both absolute and per hectare terms, the largest environmental gain has been associated with the adoption of IR cotton.

Greenhouse gas emission (GHG) cuts
GM crops have also delivered significant savings in greenhouse gas emissions. At a global level this derives from two principles sources:

- Reduced fuel use from less frequent herbicide or insecticide applications and/or a reduction in the energy use in soil cultivation. The fuel savings associated with making fewer spray runs (relative to conventional crops) and the switch to conservation, reduced and no-tillage farming systems have resulted in permanent savings in CO2 emissions;
- The use of 'no-till' and 'reduced-till' farming systems[9]. These production systems have increased signficantly with the adoption of GM HT crops because the HT technology has improved farmers ability to control competing weeds, reducing the need to partly rely on soil cultivation and seedbed preparation as means to getting good levels of weed control. As a result, tractor fuel use use for tillage is reduced, soil quality is enhanced and levels of soil erosion cut, leading to lower GHG emissions from soil.



"globally, farmers received an average of $3.59 for each dollar invested in GM crop seeds, with farmers in developing countries receiving $4.42 for each dollar invested in GM crop seeds in 2014 (the cost is equal to 23% of total technology gains)"

In 2014, the use of GM crop technology contributed to removing the equivalent of 22.4 billion kg of carbon dioxide from the atmosphere or equal to removing 10 million cars from the road for one year.

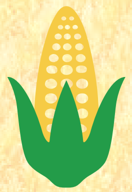
Concluding comments
GM crops have been widely grown around the world for 20 years. During this period, the technology has provided significant economic and environmental benefits to farmers and citizens.

Nevertheless, in relation to HT crops, over reliance on the use of glyphosate and the lack of crop and herbicide rotation by some farmers, in some regions, has contributed to the development of weed resistance. In order to address this problem and maintain good levels of weed control, farmers have increasingly adopted a mix of weed management strategies incorporating a mix of herbicides and other HT crops (in other words using other herbicides with glyphosate rather than solely relying on glyphosate or using HT crops which are tolerant to other herbicides, such as glufosinate). This has added cost to the GM HT production systems compared to several years ago and diminished some of the original economic and environmental gains. Despite this, the adoption of GM HT crop technology continues to deliver a net economic and environmental gain relative to the conventional alternative and, together with GM IR technology, continues to provide substantial net economic and environmental benefits.

Overall, there is a considerable body of evidence, in peer reviewed literature, and summarised in this paper, that quantifies the impacts of crop biotechnology. These impacts have largely been positive for both farmers and citizens in adopting

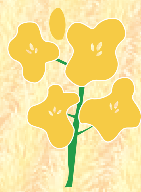
The higher yields and extra production arising from use of crop biotechnology between 1996 and 2014 has delivered an additional global production of

158.4
million tonnes soya beans



321.8
million tonnes corn

24.7
million tonnes cotton lint



9.2
million tonnes canola

18 million farmers

now use this technology each year. Without it an extra

20.7 million hectares

of land would be required for the same yield, equivalent to a third of the arable land in Brazil.

Summary of global economic and environmental impacts of using GM crop technology 1996-2014

581 million kg
reduction in pesticides & 18.5% cut in associated environmental impact

$150.3 billion
increase in global farm income

22.4 billion kg
cut of co_2 release; equal to taking 10 million cars off the road

countries. It is therefore disappointing that, during this 20-year period, UK farmers have not been provided with the opportunity to use this technology. The lack of opportunity largely reflects the poorly functioning and increasingly non science-based approach applied to the regulatory approval system for crop biotechnology in the European Union. This has contributed to most crop biotechnology research and development now being located outside the EU, where it is typically focused on agronomic and crop issues that are of little relevance or importance to UK agriculture. Leaving the EU may provide the UK with an opportunity to embrace a more science-based approach to the regulatory approval of new technology relevant to agriculture and therefore could contribute to stimulating more crop research and development of direct relevance to UK agriculture. However, due to the considerable time lag involved in undertaking research and developing products for commercialisation (including obtaining regulatory approval), any such developments are likely to take many years to come to fruition.

NOTES

1. See for example, Brookes G and Barfoot P (2016) Environmental impacts of GM crop use 1996-2014: impacts on pesticide use and carbon emissions. GM Crops 7: p84-116 and Brookes G and Barfoot P (2016) Global income and production impacts of using GM crop technology 1996-2014. GM Crops and Food, 7, p38-77. Both papers are available on open access at www.tandfonline.com
2. The author has been analysing the impact of GM crop technology around the world for 18 years and is the author of 22 peer reviewed papers on the economic and environmental impact of GM technology
3. Spring oilseed rape
4. The cost of the technology accrues to the seed supply chain including sellers of seed to farmers, seed multipliers, plant breeders, distributors and the GM technology providers
5. A typical ‘equivalent’ cost of technology share for non GM forms of production (eg, for new seed or forms of crop protection) is 30%-40%
6. By facilitating the adoption of no tillage production systems this effectively shortens the time between planting and harvest of a crop
7. Equal to 1.25 times annual use
8. The EIQ distils the various environmental and health impacts of individual pesticides in different GM and conventional production systems into a single ‘field value per hectare’ and draws on key toxicity and environmental exposure data related to individual products. It therefore provides a better measure to contrast and compare the impact of various pesticides on the environment and human health than weight of active ingredient alone. However, it should be noted that the EIQ is an indicator only (primarily of toxicity) and does not take into account all environmental issues and impacts. For additional information about the EIQ indicator, see, for example Brookes and Barfoot (2015) Environmental impacts of GM crops 1996-2013, referred to on page 1
9. No-till farming means that the ground is not ploughed at all, while reduced tillage means that the ground is disturbed less than it would be with traditional tillage systems. For example, under a no-till farming system, soybean seeds are planted through the organic material that is left over from a previous crop such as corn, cotton or wheat, or wheat/barley is planted through the organic material of a previous canola crop

The advantages of biotechnology have been seen, on a farm scale, in Europe...

GM in Europe: The experience of Spain

Soledad de Juan Arechederra
Director, Fundación ANTAMA

In the 20 years since the commercialisation of GM crops, the malfunctioning EU approvals process has meant that GM cultivation in the EU has been effectively banned, with only a very few crops ever being approved for cultivation. In 2014 farmers in five EU countries (Spain, Portugal, Czech Republic, Slovakia and Romania) planted 143,016 hectares of insect resistant biotech maize, which is still less than 1% of global GM crop production. The largest grower of GM crops in the EU is Spain, where there has been a proven record of benefits to farmers and society as a whole.

To mark 20 years of cultivation of GM crops all over the world, the ANTAMA Foundation published a report that showed the benefits enjoyed by Spanish farmers in the last 18 years thanks to the cultivation of genetically modified maize. The report concluded that the adoption of Bt maize by Spanish farmers has enabled the country to reduce maize imports by over one million tonnes between 1998 and 2015, with savings of 193 million euros. This is a significant addition to Spanish foreign trade which is deficient in this crop.

The cultivation of Bt maize in Spain over the last 18 years has seen the production of an extra 1,093,868 tonnes of crops. To achieve this production through conventional crops, it would have been necessary to increase the acreage to 106,775 hectares. This would have led to extra use of 615,778,000 m^3 of water, which could have been used for other uses such as supplying water to 746,000 people for a whole year.

Bt maize cultivation in Spain has saved 1,335 million m^3 of water during the 18 years of cultivation, thereby reducing the pressure of human activity on freshwater. In addition, cultivation of Bt maize has generated additional net carbon fixation of 849,935 tonnes of CO_2. This means that since Bt maize started to be cultivated in Spain, it has offset the annual CO_2 emissions of more than 25,000 cars.

The main economic reasons driving the adoption of Bt maize in Spain are its higher yields and lower production cost. This is due to a reduced use of pesticides, decreasing related costs, lower fumonisins (mycotoxins) in maize grain and reducing production losses by corn borer pest. Mean differences between the performance range from 7.38% to 10.53% more yield for the GM maize depending on the area and severity of the pest.

The higher yield of Bt maize translates into additional economic benefits for farmers, due to higher gross margin generated compared to conventional maize. This difference can reach up to 147 euros per hectare depending on the area and the year.

As this shows, the benefits of GM to Spain have been considerable. However, this is just a small example of the wider benefits which could be felt by farmers, consumers and the wider economy should the European approval process be improved. Political decisions at a European level, which have resulted in the continued backlog in approvals of GM products, are increasingly threatening Spanish farmers' ability to compete, with knock on effects for jobs and growth in Spain's vital farming sector. Unless we harness the benefits of agricultural technologies through a more appropriate and flexible regulatory environment our farmers will continue to compete on an uneven playing field with the rest of the world.

To allow farmers in Spain, and the rest of Europe, to be able to compete with the rest of the world the EU should ensure access to GM cotton and other varieties of corn that are more efficient in water use or those that need less nitrogen for cultivation. Europe is losing the train of agricultural biotechnology, a more important revolution than computers in the twentieth century. The obstacles to biotechnology condemn us to import food in a bullish price scenario.

Case study - José Luis Romeo, a farmer in Spain

José Luis Romeo is President of the General Association of Corn Growers Spain (AGPME), President of the Association Probio (Association of Farmers PRO-Biotechnology), an active, fourth generation farmer in Ebro Valley (Spain). He has been cultivating Bt corn since 2004, as a protection against the corn borer pest and fighting the increasing drought. "Agricultural biotechnology allows us to produce more and better." José Luis Romeo recognises that without biotech varieties "Spanish agriculture, and also European, can't be competitive." It is a technology that allows farmers to produce more and better, and to be more competitive.

Spain is a European reference point in the field of agricultural biotechnology, with 18 years of experience growing Bt maize. From 1998 to 2015, the cultivation of Bt maize has allowed Spain to reduce imports of maize over one million tons, savings 193 million euros. Bt maize cultivation has also allowed an extra production of 1,093,868 tons over the last 18 years. Spanish farmers have demonstrated its benefits and the feasibility of the coexistence of crops.

José Luis Romeo recognises that the coexistence of crops is possible and there are many ways to achieve this. Spain is an international example of coexistence, with 18 years of Bt corn cultivation sharing land with conventional and organic crops without a single problem. "The coexistence of crops is possible and is achieved through coordinating the pollinations with the neighbour or leaving adequate separation between different cultures," says the farmer.

Seeing the benefits that Bt maize is providing, farmers are demanding new biotech varieties and ask Brussels not to slow the commitment to a safe technology scientifically proven. "Spanish farmers want to have the same tools as our competitors. Outside our borders farmers cultivate GM crops and we do not have the same instruments despite competing in the same market."

Why have the vast majority of EU farmers missed out on the advantages of biotechnology?

Julie Girling MEP

GMOs are legal in the EU: we legally grow them, we legally import them, and we legally feed them to our livestock. However, an outsider may be forgiven for not knowing - or believing - that this is the case. Indeed, anti-GM sentiment in the EU is publicly perceived to be high: the Council of the European Union repeatedly fails to reach a majority in favour of GM authorisations; in the European Parliament's Committee on the Environment, Public Health and Food Safety the subject is marginalised from mainstream opinion.

How can this gulf between the legal and the political realities be explained?

In part, it is to do with risk and science communication. The anti-GM lobby rely on claims that GMO food and feed is unsafe for human and animal consumption, and that GM cultivation poses a threat to the environment and biodiversity. Of course, provisions for all of these concerns are made within the legislation: GMOs in the EU undergo the strictest safety assessments of anywhere in the world to ensure that their cultivation, import or consumption is at least as safe as that of their conventional counterparts. If the EU's independent scientific body, EFSA, concludes that a particular GMO satisfies these safety criteria, it will recommend authorisation; any GMO on the EU market today will have gone through this process. However, that message simply isn't getting through to the wider public, and this failure to adequately communicate risk assessment and management provisions is exploited by the anti-GM lobby, some media outlets and some MEPs pursuing an ideological agenda.

Not unlike what we saw during the Brexit campaign, scare stories and conspiracy theories sell: headlines about "Frankenfoods" and the corrupt and opaque nature of the EU's scientific bodies and are much more attention grabbing than any sort of statement about the latest round of safe and legal GM feed authorisations.

Furthermore, public trust in science and institutions seems to have been rocked in recent times. Studies are often quoted out of context, or portrayed disingenuously as representing the broader scientific consensus, which leave people confused, and as a result, suspicious and distrustful. When EFSA delivers a positive scientific opinion on a GM application it is immediately accused of its "flawed risk assessments" and "lack of independence" without these claims being explained or substantiated. In this context, it is no wonder that public perceptions of GM technology are so low. Thus I would go as far as to argue that many NGOs and media outlets deliberately engage in such tactics to actively promote certain ideologies and undermine scientific institutions, rather than acting - as they claim - in the interests of citizens.

Therefore the real challenge for the biotechnology sector - and indeed the European Commission (and EFSA by extension) - is how to explain the authorisation procedure to the public, and to communicate the risk assessment methodologies and risk management decisions in a clear, precise and unpatronising way which allows individuals to draw their own conclusions.

For its part, the Commission has tried to "democratise" the GM authorisation procedure in order to increase transparency and thus restore public trust in the procedure. In the Commission's 2015 Work Programme Jean Claude Juncker made the commitment that "the Commission will review the decision-making process for the authorisation of Genetically Modified Organisms (GMOs) in order to address the concerns of citizens and Member States as regards the Commission's current legal obligation to approve the authorisation of GMOs in cases where a clear majority of Member States oppose the proposal."

> "another challenge facing the biotechnology sector is how to 'sell' GMOs in the PR sense: how to generate public interest in the technology and how it can be used"

Directive (EU) 2015/412 which entered into force last year offered the first significant reform to the GM legislative framework by allowing individual Member States to opt out of the geographical scope of cultivation applications i.e. to ban cultivation of EU-approved GMOs. Despite the fact that the final agreement was not considered ideal by those on either side of the argument, it goes a long way towards appeasing some of the most acute public and political reservations over GMOs, since cultivation of GMOs is considered to be more 'sensitive' than other uses[1].

However, a more recent attempt to mirror this agreement with a proposal to allow Member States to ban imports of EU-authorised GM food and feed was a lot less successful: is has already been rejected by the Parliament, and has been sitting in Council for months without response. The issue here is that, unlike cultivation, the question of imports cannot be restricted to a particular geographic region: targeting imports has legal implications for the functioning of the EU's Single Market and international trade obligations. Furthermore, the practical reality is that all EU Member States import some GM feed to sustain their livestock sectors, and any restrictions on access to these imports could have significant economic impacts for EU agriculture.

On this basis, one could argue that the Commission's grand reform agenda has thus far fallen short of delivering any consensus on the overall 'GM question', which remains as contentious as ever.

And so the anti-GM voices continue. In an article published in The Parliament Magazine on 12 September a colleague from the Parliament stated that: "Promoting GMOs means promoting the use of pesticides", whilst another effectively advocated for a 'reform' which would lead to an end in GM authorisations. I am dismayed that after several years of re-examining this issue and attempting to increase the level of information and debate, such politically loaded and over-generalised statements are still as prevalent as ever. Lumping all GMOs together as equally "bad" is another tactic serving to fuel mistrust and misunderstanding over GM technology. For a start, allowing the import of GM feed materials will have absolutely no effect on pesticide use in the EU; secondly not all GM traits being commercialised relate to pesticide resistance (the 'Roundup-ready' varieties) - this argument fails to acknowledge disease resistant and pest resistant traits which could reduce pesticide use, or the nutritional benefits of varieties like golden rice or omega-3 producing oilseed.

These examples also serve to illustrate that there is not just a lack of information on the scientific assessment of GMOs, but also on what GMOs actually are and how one may vary significantly from another in terms of its crop and traits. Therefore, another challenge facing the biotechnology sector is how to 'sell' GMOs in the PR sense: how to generate public interest in the technology and how it can be used.

This is no small challenge. Part of the ideological opposition to agricultural biotechnology is that the GMOs submitted for authorisation come from large multinationals, and there is a - not wholly unreasonable - uneasiness among the public that these large companies essentially have some sort of ownership over food and feed. Having these companies investing in billboards explaining how great their products are will hardly serve to allay these fears. Thus the first step for the sector rather needs to be to engage in more grassroots public discourse with NGOs, consumer groups, retailers and farmers to bring some transparency to how GM technology is used in reality.

> "reducing water use, improving soil quality, increasing yields, and reducing damage from disease and pests are all significant potential benefits to be drawn from the use of GM technology"

There is an irony in the point about large companies, as the anti-GM lobby, in requiring stricter and stricter assessment criteria for authorisation, have pushed GM technology further and further into the hands of large companies, who are the only ones with the financial resources to sit out the EU's lengthy authorisation procedure. Here a possible project for policy-makers and civil society groups would be to support and encourage more public research in, and development of, GM technologies, and to somehow open up the playing field to smaller companies and research laboratories looking to develop and possibly eventually commercialise products.

As a concluding point, it is important to note that the EU has committed itself to the 2020 strategy on smart, sustainable growth; the UN drew up a list of Sustainable Development Goals to achieve by 2030. Innovation will be an essential driver in meeting these many goals, and more specifically, GM technology has a role to play. Reducing land use, reducing pesticide use, reducing water use, improving soil quality, increasing yields, and reducing damage from disease and pests are all significant potential benefits to be drawn from the use of GM technology, and could help contribute to food security and the sustainable management of resources which will be needed to sustain a future global population of 10 billion. Here the sector needs to be more explicit about how it intends to help societies - both developing and developed - to meet those goals.

It is for this reason that I remain astounded that the green lobby continues with its fight for a blanket ban on GM technology, without stopping to consider the specific benefits to be drawn from individual events which could make a real difference for communities and the environment. I would never advocate wholly in favour of GM technology over other agricultural practices, but I think that under a satisfactory regulatory regime - as, for example, already exists in the EU - GM technology can be one of the tools which help us to meet the challenges facing us today, and in the future.

NOTES

1. Recital 6 of the Directive outlines how cultivation "is an issue with strong national, regional and local dimensions, given its link to land use, to local agricultural structures and to the protection or maintenance of habitats, ecosystems and landscapes".

Precision breeding needs smarter regulation

Huw D Jones PhD, CBiol. FRSB.
Professor of Translational Genomics for Plant Breeding
IBERS, Aberystwyth University

Unpredictable and more frequent extreme weather events along with hard-to-manage weeds, pests and diseases are placing unprecedented pressures on farming and on plant breeding in particular. We urgently need tailored genes for smarter, more resilient crops that protect themselves from biotic and abiotic stresses with fewer chemical applications. A failure to get this right will result in less efficient agriculture leading ultimately to; higher food prices, more environmental degradation and disputes over water and land. **These challenging times call for agricultural policy and regulatory oversight that protects consumers and the environment while enabling research, innovation and investment towards profitable and sustainable farming.** The public and private research base is ready and competent to deliver but, certainly in the EU, near-market innovation in molecular plant genetics is stagnant and the current regulatory oversight of modern crop biotechnology is failing.

The blunt regulatory instrument that places all new plant varieties into either a GMO or a non-GMO category is fundamentally flawed. The trigger is based on outdated and ill-defined concepts of genes and recombinant DNA processes which is being further challenged by new methodologies such as gene editing.

For innovatory modern molecular breeding to flourish there is an urgent need to move away from this binary, all-or-nothing approach to risk assessment of biotechnology. It needs to be accepted that the increasing technological breadth of modern breeding demands a nuanced and graduated oversight that is proportionate to the risks and benefits of the products. For instance, genetic improvements derived from simple gene editing that are analogous to, and indistinguishable from, spontaneous natural mutations that already exist in crop species at large, clearly should not be regulated as though they were conventional GMOs. However, they should not fall outside all regulatory oversight either. Instead they need a light-touch regulatory procedure, commensurate with the low potential risks, to confirm the intended targeted edits and the removal or deactivation of the mutagen. At the same time, these approaches must be accompanied by clear, effective and open dialogue to regain the trust of consumers who are understandably baffled by the conflicting claims of risks and benefits resulting from different plant breeding methods. Current developments in gene editing give us a unique opportunity to redesign out-dated regulations and at the same time to communicate the exciting science, and the benefits and the risks of modern plant breeding.

Gene editing is significant and timely in many ways. It represents a major breakthrough technology for research that is now being applied to plant and animal breeding. However, it also serves a secondary function; to expose basic inadequacies in process-based regulatory definitions of conventional biotechnology that have failed to evolve with advancing scientific understanding. Simple gene editing does not give rise to a GMO and should not be regulated as such.

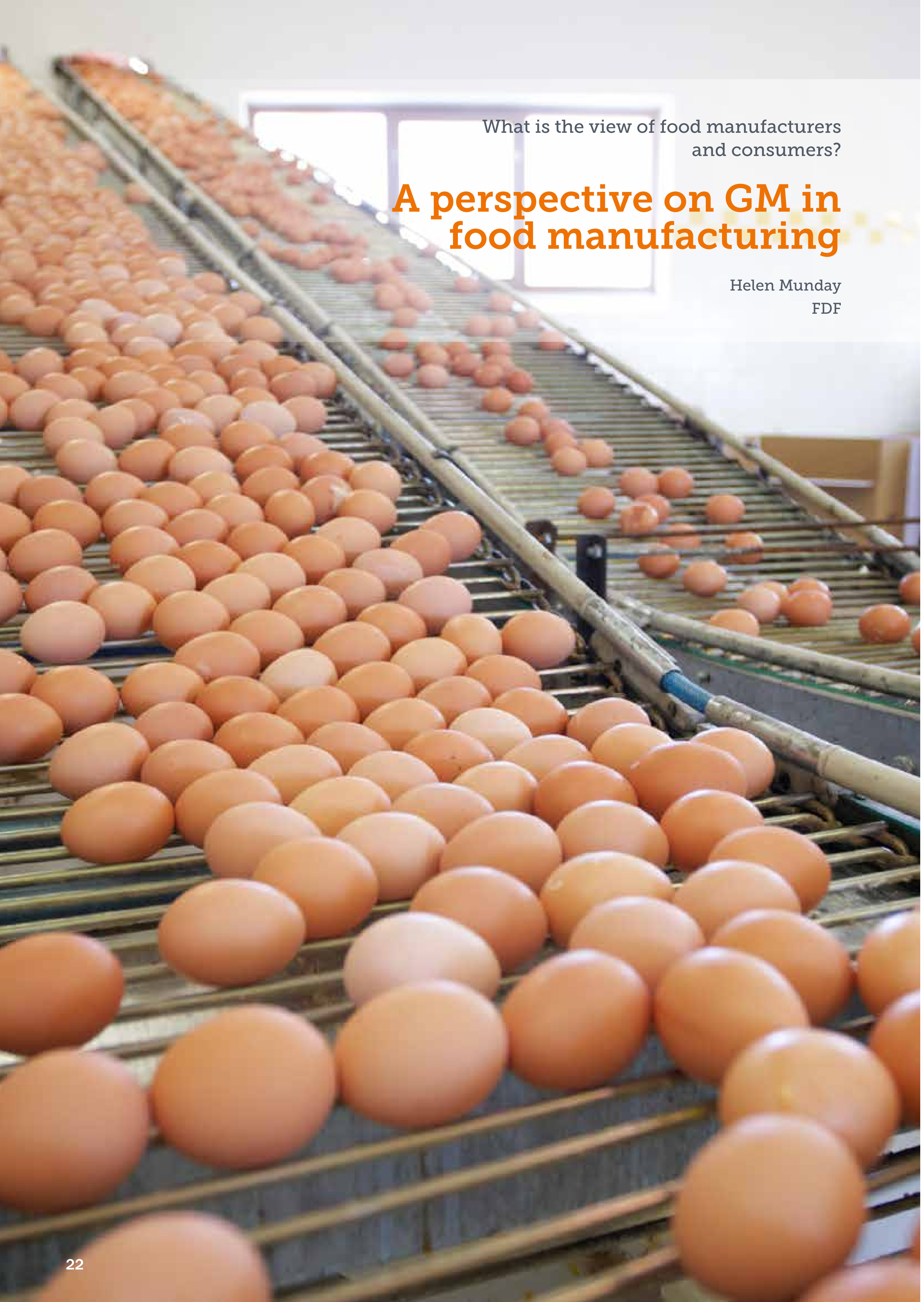
I agree with the logic of the recent USDA ruling that a gene edited maize developed by DuPont-Pioneer is not a regulated genetically engineered product in the USA. This targeted mutation alters the starch quality in the maize grain to make it waxier, which brings functional advantages including beneficial effects of slower digestibility and various non-food uses. The gene edit in this new variety is analogous to the hundreds of similar spontaneous mutations in the same gene found naturally in maize. Waxy maize with conventional mutations are already cultivated but these varieties invariably yield less than non-waxy elite maize varieties. The power of gene editing is such that beneficial mutations can be recreated directly and cleanly in elite, high-yielding commercial breeding lines; saving many years of complex introgression via conventional backcrossing of naturally-found mutations which will also drag in deleterious genes and anyway has no certainty of success.

To date, the USDA has stated that at least five products generated using gene editing are not regulated products. Also, agencies in Argentina and Brazil have recently published guidance for gene edited crops. Canada has a largely trait-based regulatory system that should smoothly accommodate gene edited varieties as they come to market. However, in the EU there remains complete uncertainty over how gene edited products will be regulated. Despite being the second largest importer of GMO soybeans in the world and with approximately 80% of its animal feed incorporating GMO soya or maize, the EU still has no plans for handling the import or cultivation of gene edited crops.

Several non-governmental organizations (NGOs) with a history of campaigns against biotechnology including TestBiotech, Greenpeace and Friends of the Earth recently published an open letter to the European Commission (EC) urging it to ensure (among other things) "that organisms produced by these new techniques will be regulated as genetically modified organisms under existing EU regulations (Directive 2001/18)". This position cannot be scientifically justified for simple gene edits. On the other hand, several EU member states independently concluded, as did the USDA, that a gene edited canola variety made by the US firm Cibus was not a GMO. The position is now further complicated by the French Council of State who in October this year asked the European Court of Justice (ECJ) to rule on a series of points regarding whether organisms obtained by conventional mutagenesis or gene editing constitute genetically modified organisms under EU legislation, whether member states have some freedom of interpretation and how precautionary principle applies in such cases. The judgement is expected in about 18 months. We can only hope the ruling is better formulated than the infamous Bablok and Others v Freistaat Bayern case in 2011 when the ECJ concluded that pollen was an ingredient rather than a constituent of honey and came close to ending all amateur bee keeping in the EU and blocking honey imports from North and South America.

> "despite being the second largest importer of GMO soybeans in the world and with approximately 80% of its animal feed incorporating GMO soya or maize, the EU still has no plans for handling the import or cultivation of gene edited crops"

Europe has lost the commercial biotechnology activity it built up during the 1980s and 1990s but still has excellent basic plant science research. All elite, research-intensive university biology departments are inevitably using some form of gene editing in their research today. The EU (and post-Brexit, maybe also an independent UK) has a unique opportunity to set a future regulatory environment that will nurture and support the translation of that research into new products like medicines, diagnostics and plant varieties. However, that is possible only if innovation and competitiveness is not stifled by overly prescriptive or disproportionate regulations; and if the public are confident that they and the environment are adequately protected.



What is the view of food manufacturers and consumers?

A perspective on GM in food manufacturing

Helen Munday
FDF

Food and drink manufacturers in the UK have a proud history of providing safe food to consumers and indeed it is a well-used phrase that nowhere in the world is it safer to eat than in the UK. Added to this are the famous brands that members of the Food and Drink Federation produce, which are well known and loved by consumers. Consumers know that safety is an important factor when making food purchases, but it is also true that in most cases, safety is not at the front of mind for shoppers, as most people will trust that the manufacturer has taken care of such things. For them it is a given. In the vast majority of cases, this is a sensible and an obvious approach, but on occasions safety does make the headlines. Such was the case when the horsemeat incident broke. In these instances, consumers do have safety high on their list of considerations and the usual hierarchy of choice of price, convenience and health is reconsidered.

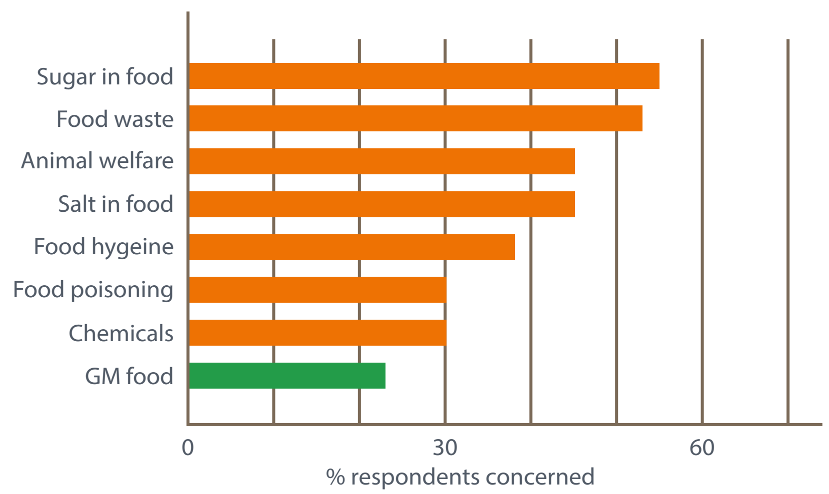
Understanding the concerns that citizens have about the food and drink they buy is a major undertaking of the Food Standards Agency (FSA). On a biannual basis the FSA places six questions as part of a regular TNS face-to-face omnibus survey, in order to monitor key FSA issues. The last wave of the survey was conducted in May 2016.[1]

In this last survey the food safety issues of concern (including both spontaneous and prompted responses) most frequently reported by respondents were food hygiene when eating out (38%), food poisoning (30%), and chemicals from the environment (30%). The wider food issues of concern most frequently reported were the amount of sugar in food (55%), food waste (53%), the amount of salt in food (45%) and animal welfare (45%).

In the most recent survey on wider concerns on food safety, the topic of Genetically Modified (GM) foods can be found in the bottom third of concerns with 7% of respondents saying spontaneously that they are concerned and 23% saying they have a concern either spontaneously or when prompted. This is a fairly consistent finding to recent FSA surveys. The next item down of concern on food safety is the feed given to livestock. This is a slightly lower level of concern in comparison to GM foods but has been increasing slightly.

Thus for the consumer, concerns about GM in food are at a reasonably low level but it is possible that this could change including any increase in media or other types of coverage. Of course negative coverage could impact negatively on the consumer, but equally positive coverage could have the opposite effect.

Food safety concerns



Core to the responsibilities of manufacturers is supplying safe, affordable, nutritious and enjoyable food for all. But no two consumers are the same and each will have their hierarchy of needs which will influence making numerous choices every day. It is the role of manufacturers to provide choice to meet the needs of all these consumers as fully as possible.

Manufacturers have always looked to policy makers to make evidence based and proportionate decisions, whether inside or outside the European Union (EU) this will continue to be the case. The decision to leave the EU taken during 2016 has created a sense of some uncertainty throughout the AgriFood arena and it is a clear aim of the manufacturing sector to maintain confidence in food safety. At the same time, we support the use of technology to improve access to affordable food and facilitate food security.

This is why the FDF has always welcomed initiatives which facilitate the managed introduction of GM crops to UK agriculture and the provision of associated information along the food chain to food manufacturers and their customers. That said, manufacturers will always have the interest of consumers front and foremost, but it is to be hoped that these consumers are informed of any possible risks and benefits in a very factual and dispassionate way.

Food and drink manufacturing has innovation at its core and through the adoption of new technologies, be they in engineering, food science or other fields, the sector will strive to meet the needs of consumers better year on year.

NOTES

1. Biannual Public Attitudes Tracker, FSA, https://www.food.gov.uk/sites/default/files/tracker-wave-12.pdf

Conclusion

Mark Buckingham
Chair of the Agricultural Biotechnology Council

The anniversary of 20 years of large scale commercial cultivation of GM crops falls at a very interesting time for UK food and farm policy.

As the essays in this collection illustrate, not only do we now have the evidence about how farmers use GM and the economic and environmental benefits it can bring, but we are also on the verge of a new range of tools developed from advances in genetic knowledge and technology.

abc is very grateful to the authors, renowned experts and industry leaders for their willingness to share experiences and knowledge in this way.

The contributors to this collection have demonstrated not only the benefits of GM crops and the great potential of new innovations, but also the political challenges faced in Europe which has led to the stifling of the technology in terms of cultivation in this region. Significantly, thanks to expert contributions from the NFU and the FDF, we have also read how there is no clear opposition to the technology among consumers and that British farmers see adoption of new innovations as essential to securing their future.

Yet, 20 years after the first large scale commercial cultivation of GM crops, Europe risks becoming the museum of world agriculture. The next 20 years will take us to 2036, agriculture and global natural resources both in the UK and around the world face huge challenges in that time. We risk imposing a great cost on farms and on the environment if we continue to indulge in the same prolonged and shallow debate that has too often characterized GM since 1996.

The way forward is consideration of the evidence followed by policy that facilitates choice. The UK is well placed to lead, we have a strong science base, and a track record of evidence based agricultural policy. The UK has a world leading food and farming sector that prides itself on delivering choice to consumers and in championing tools that improve the quality, affordability and environmental footprint of food and farming products.

Within these essays is the story of technology that has changed farming and a model for the debate and policy framework that can allow us all to benefit in coming decades from new generations of tools that advancing knowledge and experience is making available.

Appendix

Global impact of changes in the use of herbicides and insecticides from growing GM crops 1996-2015

Trait	Change in volume of active ingredient used (million kg)	Change in field EIQ impact (in terms of million field EIQ/ha units)	% change in ai use on GM crops	% change in environmental impact associated with herbicide & insecticide use on GM crops	Area GM trait 2014 (million ha)
GM herbicide tolerant soybeans	+5.5	-7,623	+0.2	-14.1	81.8
GM herbicide tolerant & insect resistant soybeans	-1.5	-143	-0.9	-2.7	9.5
GM herbicide tolerant maize	-213.7	-6,811	-8.4	-12.6	46.2
GM herbicide tolerant canola	-21.8	-763	-17.2	-29.3	8.9
GM herbicide tolerant cotton	-23.1	-585	-7.3	-9.9	4.6
GM insect resistant maize	-79.7	-3,522	-51.6	-55.7	48.3
GM insect resistant cotton	-249.1	-11,122	-27.9	-30.4	23.4
GM herbicide tolerant sugar beet	+2.0	No change	+32.5	No change	0.47
Totals	**-581.4**	**-30,570**	**-8.2**	**-18.5**	

Biographies of contributors

Professor Sir John Beddington CMG FRS
Senior Advisor, Oxford Martin School

Professor Sir John Beddington is Senior Adviser at the Oxford Martin School, and was previously Professor of Applied Population Biology at Imperial College London.

From 2008- 2013, Sir John was the Government Chief Scientific Adviser (GCSA). Sir John has previously been advisor to a number of UK Government departments including the Foreign and Commonwealth Office, the Department for Environment, Food and Rural Affairs, the Ministry of Defence and the Cabinet Office. He has also advised several Governments and international bodies.

He was, for six years, a member of the Natural Environment Research Council. In June 1997 he was awarded the Heidelberg Award for Environmental Excellence, and in 2001 he became a Fellow of the Royal Society. In 2004 he was awarded the Companion of the Order of St Michael and St George by Her Majesty the Queen and in June 2010 was awarded a knighthood in the Queen's Birthday Honours.

Dr Ella Adlen
Research Assistant, Oxford Martin School

Dr Ella Adlen joined the Martin School in February 2014 as Research Assistant to Sir John Beddington. Before working for the Oxford Martin School, she worked for Sloane Robinson in the City of London as an equity analyst for 6 years. During this time she researched diverse global industries and trends ranging from nuclear energy to emerging market luxury goods demand.

She has a PhD in genetic epidemiology and a multidisciplinary degree in Human Sciences, both from the University of Oxford.

Dr Helen Ferrier
Chief Science and Regulatory Affairs Adviser, NFU

Dr Helen Ferrier is the National Farmers' Union's Chief Science and Regulatory Affairs Adviser. She leads the organisation's policy work on agricultural science and research, and biotechnology, covering all sectors of farming. Based at NFU HQ in Warwickshire, she leads a policy team covering plant health and pesticides, farm safety, skills and training, transport, employment and better regulation.

Helen is a director of the Rothamsted Research Association Board and is a member of the Institute of Food Science and Technology. Before joining the NFU in 2004, Helen was a research scientist at Imperial College London, working on probabilistic modelling of dietary exposure to pesticides. She has a background in environmental science and technology.

Soledad de Juan Arechederra
Director, Fundación ANTAMA

Soledad de Juan Arechederra is an Agricultural Engineer from the Universidad Politécnica de Madrid. She is the head of the ANTAMA Foundation, a non-profit organization whose purpose is the promotion of new technologies applied to agriculture, the environment and food. She has more than twenty years of experience in the field of agronomy within private enterprise and from the management of public investment programs in the rural world.

Graham Brookes
Agricultural Economist, PG Economics UK

Graham Brookes is an Agricultural Economist with PG Economics UK (www.pgeconomics.co.uk). He has been analysing the impact of GM crop technology around the world for 18 years and is the author of 22 peer reviewed papers on the economic and environmental impact of GM technology.

Julie Girling MEP
South West England and Gibraltar

Julie Girling has served as a Conservative Member of the European Parliament for South West England and Gibraltar since 2009.

She is currently the Coordinator for the European Conservatives and Reformists Group on the Committee on Environment, Public Health and Food Safety. She also sits on the Committee on Agriculture and Rural Development.

During her time in the European Parliament she has worked on a number of important legislative files covering areas such as food safety, reform of the Common Agriculture and Fisheries Policies, biodiversity, chemicals, air quality, and animal welfare.

Huw D Jones PhD, CBiol. FRSB
Professor of Translational Genomics for Plant Breeding, IBERS, Aberystwyth University

Huw Jones recently moved to his current post at Aberystwyth University after 20 years at Rothamsted Research. He has a global reputation in plant molecular genetics, the development of cereal transformation systems and the application of biotechnology approaches to study gene function. He has interests in applied genome editing and functional genomics research but also in risk assessment and regulatory policy of biotechnology.

He has held three Defra licences for non-commercial, field trials of GM wheat in the UK. He is Honorary Professor in the School of Biosciences, Nottingham University, an honorary visiting researcher at Rothamsted and vice-chair of the GMO panel, European Food Safety Authority. He has published over 100 research papers, books and other articles.

Dr Helen Munday
Chief Scientific Officer, FDF

Helen Munday has recently re-joined the Food and Drink Federation (FDF) as Chief Scientific Officer (CSO) having worked for the trade association as Director of Food Safety and Science earlier in her career. In her role as CSO, Helen is accountable for the sustainability and the diverse food safety and science policy briefs at FDF, and also contributes to health and wellbeing policy.

Helen has a wealth of experience of the food and drink industry, having previously held senior global roles in companies such as Mars and Coca-Cola. Helen has also worked as Lead Technologist in AgriFood at Innovate UK. Helen has a high level of expertise in R&D, Scientific and Regulatory Affairs as well as Product Development and Innovation. She is a registered nutritionist and Fellow of the Institute of Food Science and Technology.

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