Planting the future

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A non-technical summary of *Planting the future: opportunities and challenges for using crop genetic improvement technologies for sustainable agriculture*, a report by the European Academies Science Advisory Council

Foreword

With a burgeoning population, a finite supply of land and the prospect of climate change, this century will see world agriculture placed under ever greater pressure as it struggles to increase food production sustainably. Agricultural biotechnology is among the tools by which the challenge can be met. But one of biotechnology's most promising achievements, the creation of new plant varieties by genetic modification, continues to arouse suspicion, and nowhere more so than in Europe. This EASAC report reviews the economic, scientific and social consequences of current European Union policy on genetic modification and other techniques, and argues that Europe and the rest of the world have much to gain by reassessing and revising it in the light of the accumulated evidence.

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Challenges to agriculture

A billion people on this planet experience hunger; another billion eat a diet lacking in essential vitamins and minerals. The world's population continues to grow and, over the next 40 years, agricultural production will have to increase by some 60%. Meanwhile a quarter of all agricultural land has already suffered degradation, and there is a deepening awareness of the long term consequences of a loss of biodiversity. The global pattern of food consumption too is changing, with rising affluence fuelling a greater demand for meat. All this with the prospect of imminent climate change. To say that agriculture faces challenges over the coming decades is to express the problem mildly.

The productivity of wheat, the most widely grown crop in the world, has remained relatively stagnant and production levels do not satisfy global demand. Current plant breeding efforts to improve yields and also the nutritional composition of wheat make use of all the plant breeding technologies available.

Like many of its constituent members, the European Academies Science Advisory Council (EASAC) has a track record of drawing attention to the relevance of genomic and other agricultural biotechnologies to the social and economic future of Europe. Its new report (the full version of which is available at www.easac.eu) makes the case for policies that recognise the value of these technologies, and promote their development and use. One of the tools available to plant scientists is the breeding of new crop varieties using genetic modification, a technique that has generated much controversy in recent decades. The outcome, in Europe, has been its widespread rejection.

Although genetic modification (GM) has attracted the closest attention, it is only one of a clutch of new breeding technologies to have been developed in recent decades. The term GM is generally taken to mean the introduction into an organism of genetic material from a different species. But scientists have also devised other forms of intervention in which, for example, the added material comes from another member of the same species. The material itself may or may not have been modified in some way. By these and other methods it is possible to create a wide variety of potentially beneficial genetic changes.

Although making no claim that GM technology represents the only or even the most important way forward, the report argues that it must be allowed to take its place among the scientific advances that European plant breeders and farmers can call upon. Given the scale and severity of the challenges to agriculture we cannot afford to neglect any of the finite number of strategies at our disposal. No new technology should be excluded on purely ideological grounds.

These challenges are not confined to the developing world. Countries of the European Union (EU) will face particular problems with the use of fertilisers, the availability of water and the degradation of soils. For the past decade at least, increases in farm yields of many major crops have been limited or non-existent, and the introduction of new EU legislation requiring farmers to reduce their reliance on crop protection chemicals will exacerbate the problem. The past focus of the EU's Common Agricultural Policy having been on constraining rather than increasing production, farming efficiency has ceased to be a priority. EU countries now grow less than half the food and animal feed consumed within their own borders, and Europe is the world's largest importer of agricultural commodities.

The need to increase agricultural productivity and efficiency in developed as well as in developing countries is now widely accepted. To confront these challenges successfully will require policies and actions that capitalise on all scientific advances generated in the EU and elsewhere.

The right policies for the best technology

Producing more food sustainably requires crops that make better use of limited resources including land, water and fertiliser. This can be achieved through the exploitation of plant genetic resources, and EU researchers have contributed greatly to the relevant biotechnology. But so long as EU policies on farming and the environment are out of alignment with the need to innovate, ambitions to improve agriculture will be thwarted.

High-quality science is self-evidently important in driving innovation, but it is also needed to inform rational policy decisions. As the European Commission itself is aware, concerns have already been voiced about the long-term competitiveness of those European industries contributing to the continent's bioeconomy (the sum total of economic activity derived from scientific and

Cotton damaged by cotton bollworms. Insect-resistant GM cotton now accounts for 80% of global production, which has led to significant reductions in the use of chemical insecticides needed during cotton production.

research activity focused on biotechnology). Other regions of the world have been moving ahead of Europe.

Conventional crop breeding takes many generations and is relatively imprecise. The scientific basis of all crop improvement is the identification of genes that determine specific traits. Genetic modification is able to achieve goals that would be harder if not impossible to reach using older methods. But as can be seen from Box 1, few GM crops so far developed have conferred much economic benefit on agriculture in the EU.

Its lack of enthusiasm for GM crop improvement has increased the EU's dependency on food and feed imports, and has implications for its scientific research and future industrial competitiveness.

The case for a rethink

It is now more than ever possible to judge the impact of GM crops endowed with herbicide tolerance or insect resistance or both. The scientific literature shows no compelling evidence to associate

Box 1

GM crops worldwide

- In 2012, 17.3 million farmers planted GM crops. Since 1996 the area so cultivated has increased 100-fold: from 1.7 million to 170 million hectares.
- Globally more than 70% of soy beans and more than 80% of cotton are of GM origin.
- Of the 28 countries that planted GM crops in 2012, 20 were in the developing world. The area of GM crops under cultivation has overtaken that in developed countries.
- The economic benefit of GM crops to developing countries in 2011 has been estimated at US$10.1 billion.
- In the EU only two GM crops are approved for commercial cultivation: insect resistant maize, and potatoes with modified starch for industrial use. Of the total area of GM maize grown in the EU in 2012 (129,000 hectares) one country, Spain, contributed more than 90%.

such crops, now cultivated worldwide for more than 15 years, with risks to the environment or with safety hazards for food and animal feed greater than might be expected from conventionally bred varieties of the same crop.

Claims of adverse impacts have often been based on contested science, and some critics have falsely attributed the effects of a specific trait to the means used to introduce it to the plant. Cultivating a GM crop variety with increased herbicide resistance, for example, may prove detrimental to the environmental if the farmer over-uses that herbicide. But the same would be true of herbicide resistance introduced by conventional breeding. Any new tool or technology can have unintended and unwanted effects if used unwisely.

No single technology can be regarded as a panacea; but previous work by EASAC and its constituent academies has made a strong case that the improvement of crops through genetic modification should be part of an inclusive approach to the future of agriculture in Europe. If the European bioeconomy is to flourish, EU policy-making institutions need to combine their support for innovation with a more proportionate duty of regulation.

What other countries are doing

European policies exist in a global context; what happens in Europe affects the rest of the world, and vice versa. The EASAC report assesses this wider aspect of policy-making in three ways: by examining what is happening in countries that have chosen to adopt GM crops; by assessing the impact on Africa in particular of EU policies and practices with respect to GM crops; and, in the light of international experience, discussing whether regulation of crop genetic improvement technologies by the EU could be improved by paying more attention to the evidence. A new approach in this regard could have far-reaching consequences for food security, sustainable agriculture, environmental quality, scientific endeavour, European competitiveness and EU relationships with other countries.

The full report looks at the use of GM crops in Argentina, India, Australia, Brazil and Canada as well as Africa. Their various experiences offer insights into the potential benefits of GM technology, necessary precautions when using it, and the optimum approach to regulation.

Argentina was an early adopter of GM. By now its cumulative gross economic benefit is estimated to be more than US$72 million, mostly from soybean production. About 50% of the crop sown in the 2002–03 season was planted in previously uncultivated areas. Recent years have not been entirely problem free, often because farmers, knowing their crop is more resistant to herbicide, have used that herbicide too freely.

Bt cotton, approved for use in ***India*** in 2002, is genetically altered to manufacture a protein from the bacterium *Bacillus thuringiensis* which, when ingested by the bollworm, kills it. The use of Bt cotton has brought about a 24% increase in yield per acre, and a 50% gain in profit to smallholders. But its use is still controversial, partly on account of a general concern with commercial influence over the agricultural sector, but also because of perceived fears for human health and the environment. Opposition has been driven largely by a coalition of non-governmental organisations connected to international advocacy movements.

Nearly all the soybeans produced in the United States of America, Brazil and Argentina, the main global exporters for this crop, are of GM origin. Although GM soybean is not approved for cultivation in the EU, according to the Food and Agriculture Organization of the United Nations, soybean imports in the EU (mostly destined for feedstock) in 2010 were worth US$ 31 billion.

The broad conclusion to be drawn from the Indian experience is that if GM crops are to be maximally beneficial they need to be introduced as part of a strategy for improving overall economic development in rural areas. This would include improvements to rural infrastructure, easier access to education and financial credit, and a remedy for the progressive fragmentation of already small farms.

More integrated policy making already shapes the use of GM in ***Australia***. GM cotton, grown there since 1996, now makes up around 95% of the crop and is used as part of an integrated pest management system rather than a stand-alone solution. No new breed of plant can, by itself, solve all the farmer's problems.

Brazil is the second largest exporter of soybeans in the world, and the crop is substantially GM. One of the consequences of the country's adoption of the technology has been a big government investment in agricultural biotechnology research. Embrapa (Empresa Brasileira de Pesquisa Agropecuária), one of the world's largest public-sector tropical agriculture organisations for research and development, has an annual budget of over US$1 billion, and more than 2,300 researchers at 42 centres around the country. Among the GM crops under development are sugarcane with resistance to the sugarcane giant borer, and coffee with resistance to the coffee borer beetle and to nematode worms. Brazil is emerging as a major agricultural technology provider.

Finally, in ***Canada*** new plants are regulated on the basis of the traits they possess, not according to the method used to introduce them. This approach acknowledges the fact that it is the product not the process that warrants regulation.

Africa: GM needs, problems and potential

The report places special emphasis on agriculture in Africa, not least because this sector accounts for about two-thirds of full time employment in continent and more than half of its export earnings. Much of African agriculture has been dynamic and adaptive, but increased production still lags behind population growth: a deficit likely to be exacerbated by degradation of natural resources and by climate change.

About one-third of global production of oilseed rape (canola) is of GM origin, although this GM crop has not been approved in the EU. Oilseed rape has both food and industrial applications.

GM crops are not the only solution to Africa's problems; but deployed wisely and sustainably they offer the prospect of resistance to pests and diseases, of coping with erratic weather patterns, and of boosting the micronutrient content of staple crops. Although four countries (South Africa, Egypt, Sudan and Burkina Faso) currently grow GM crops commercially and field trials are underway elsewhere, attempts to introduce the technology have had a troubled history in Africa. Some of this is attributable to the influence of the EU. Consumer organisations have put pressure on developing countries not to introduce these crops, and exaggeration of the alleged risks by European sceptics has created difficulties for African policy-makers.

According to some commentators, the EU has used technical and other assistance to persuade African governments to take an unduly precautionary approach to the regulation of GM technology. Moreover certain international NGOs with headquarters in Europe (some part-funded by EU institutions) have encouraged anti-GM crop activism in Africa. African countries have also become concerned that anti-GM sentiment could block their export of GM crops to EU markets. And even if the EU were to accept them, they would need to be labelled as GM: something not required by other markets and which would therefore create the expense and difficulty of separate handling.

Confirmation of the hopes and fears surrounding GM in Africa has emerged during meetings between EASAC and NASAC, the Network of African Science Academies. Although the European Commission's past efforts in funding and organising research and training workshops are acknowledged as having been helpful, it is now less common for African countries to form international research and development partnerships with EU countries. Instead they favour Asia and North America.

In spite of these differences African countries still believe that working with EU institutions and member states could be mutually beneficial. Europe can learn from African experience in defining local needs and opportunities. Africa still has a need for technical support and training in the tools of biotechnology in general. Where collaboration makes sense it would be desirable to move the focus of activity from universities and laboratories in Europe to their counterparts in Africa itself. But progress in the area of GM in particular will depend on efforts to address misperceptions about it by politicians and the general public in the EU, and to discourage their repetition in developing countries.

Bananas and plantains represent a major food and cash crop in Africa: 70 million people depend on them for their livelihood. Improving bananas with conventional methods is very difficult because they are sterile. Genetic transformation is hence a promising strategy to develop varieties that are more nutritious, and resistant to major pests and diseases.

Lessons for the EU

The export of agricultural commodities is an increasingly important part of the economy of most of the countries reviewed in the report. This is not so for the EU. One result is that member states have little incentive to exploit their science and technology in agricultural innovation. A further consequence is that some areas of basic science relevant to agriculture, and its translation into practice, are progressing less rapidly in the EU than elsewhere.

When considering the impact of GM crops it is essential to distinguish between any specific effect of the GM technology itself, and the consequences of other changes in agronomic practice or social development occurring at the same time. The first generation of GM crops, when so considered, show benefits that have been acquired without any greater adverse impact than might be associated with any other novel technology used in plant breeding. It is also clear that putting in place streamlined, transparent and effective regulatory frameworks encourages investment in the technology.

National academies of science can help their countries' governments in policy formation by developing effective advisory roles based on the available scientific evidence.

Future ambitions

The applications of GM technology already described are not the end of the story, but merely the beginning. Plant scientists foresee the introduction of many more crop varieties with an innate resistance to plant pathogens obviating the need for chemical spraying. Adaptation to climate change is another looming issue. Northern Europe will most likely experience warmer and more humid weather rendering crops more at risk to insect pests and fungal pathogens; crops in southern Europe will have to adapt to drier conditions. New and improved crop traits will be essential, and can be created swiftly and more reliably using GM methods.

Some developing countries take these possibilities very seriously and are acting accordingly. Asia is predicted to be a major source of future GM products. The Chinese government, for example, has committed itself to GM food crops through major scientific investment in rice, maize, rapeseed, soybean, sweet pepper, papaya and wheat variously to improve yield, quality, drought and salinity tolerance, nutritional value and pest-resistance. The Food and Agricultural Organization of the United Nations recently reported that the considerable quantity and variety of GM crops now in the pipeline may be commercialised in developing countries within the next 5 years.

The case for new policies …

Having reviewed more than 2,000 studies the Swiss National Science Foundation recently confirmed that no health or environmental risks related to GM technology have been identified. And as the American Association for the Advancement of Science has pointed out, GM crops are the most extensively tested ever to be added to the food supply. GM crops and their non-GM counterparts are nutritionally equivalent. And the beneficial impact of GM can be dramatic. The adoption of insect-resistant cotton and maize, for example, has brought about big declines in major pests in the USA and in China. Evidence is emerging that applying less pesticide to plants engineered to resist pests leads to an increase in natural insect predators. Economists estimate that world food price increases would be 10–30% higher without GM crop cultivation.

Rice accounts for a fifth of all calories consumed by humans globally. Efforts to improve rice nutritional content (proteins and essential nutrients such as vitamins) and resistance to pests and diseases cannot rely on conventional plant breeding techniques alone.

Europe, however, risks finding itself on the sidelines. As the items listed in Box 2 suggest, there is now a compelling case for the EU to re-examine its policies governing agricultural biotechnology.

A reassessment of EU policies leading to more uptake of GM and other crop genetic improvement technologies would have several desirable consequences. These include helping to make food production in Europe more sustainable, increasing EU competitiveness in agricultural innovation, increasing non-food biomass production, and reducing the EU global footprint associated with a heavy reliance on imported agricultural products. At a time when chemical protection for crops in Europe is being reduced, there is a need to find new ways to defending crops against pests and diseases. GM technology can help.

Box 2

Europe: the price of rejecting GM crops

- Current EU regulations add to the time and cost of new crop development in Europe: on average four years and €7 million direct costs per variety.
- In 2011 the EU conducted the lowest number of field trials since 1991 when records began.
- Field trial vandalism and other extreme opposition by anti-GM activists have created higher costs for approved field trials in addition to already substantial regulatory costs.
- There is a backlog in pending GM crop applications in the EU.
- Only the largest seed companies have the financial resources to seek GM approval. Smaller companies are deterred, as are new spin-offs from public sector plant science research.

… and for new regulations

GM crops are currently governed by directives on the deliberate release into the environment of genetically modified organisms (GMOs) for cultivation, and on the contained use of GMOs, and also by a regulation on GM for food and feed. Quite reasonably their legal framework embodies the precautionary principle. But in its application an essential caveat is sometimes neglected: that a sensible interpretation of the precautionary approach requires the risks of what is planned to be compared with those posed by alternative paths of action, or by not adopting it at all.

Even if a rigorous application of the precautionary principle was justified in the early and less certain days of GM crops, the merit of maintaining this stance when there is now far greater certainty is surely open to question. The level of scrutiny applied to this and other genetic improvement technologies must be reassessed to ensure that

EU regulation is not disproportionate, and so liable to stifle innovation. The current approval system – expensive, time-consuming and inappropriately focused on the technology for introducing a trait rather than on the resulting product – is doing exactly that.

As already explained, not all plants created through the use of new breeding techniques contain genes foreign to the species, so one immediate consideration for EU regulators is to confirm that when plants do not contain foreign DNA, they do not fall within the scope of GMO legislation. This clarification would boost the competitiveness of EU plant breeders, the group responsible for much of the worldwide effort already invested in new techniques.

Even when recommendations have been made, politicians – mindful of their electorates – may chose to ignore them. EU member states may invoke a safeguard clause in the GMOs directive that where there is a 'justifiable reason' to consider that an authorised GMO constitutes a risk to human health or the environment, its use or sale within their territory may be restricted or prohibited. Several EU states have indeed invoked this clause.

EASAC suggests that a radical reform of GMO legislation is now warranted. The aim must be to redirect its focus from technology to product regulation as a goal, and to risk–benefit rather than risk alone.

Damage to EU science and technology

The slow and unpredictable pace of GM crop regulatory approval and commercialisation is harming European research and development both private and public. This is weakening the capacity of the EU to develop solutions for its own agricultural needs and to tackle global challenges. Instead of exporting advanced seed and new agricultural technologies the EU is, in effect, exporting qualified researchers.

A great deal of innovative thinking has gone into the development of technologies for crop genetic improvement. It would be unfortunate if EU regulation were to prove so burdensome that the 'cost of entry' could be afforded only by large multinational companies interested in markets for globally traded crops.

One obstacle to change is the attitude of the public to genetic manipulation. Surveys across the EU continue to report negative views of GM food. But public attitudes are not immutable. And what people actually do may not always reflect their stated view. When GM foods are available on the shelves, consumers are often willing to buy them. The question of intellectual property has also ignited controversy; many people feel that genetic knowledge should not be patented. But this may be a diminishing issue. Although the first generation of GM products were the intellectual property of multi-nationals, more recent GM crop developments in Africa and elsewhere have often been publicly funded with support from international foundations and agencies. More intellectual property is now shared or licensed free for public use. But while suspicion lingers on, the scientific community needs to continue engaging with the public about the value of GM, and do so in ways understandable to the non-specialist. Taking forward the public dialogue is vital to ensure that policies are based on a shared vision of the future and to explore appropriate governance frameworks to include stakeholders and members of the public. EASAC and member academies acknowledge their responsibility to help encourage public dialogue to stimulate debate and inform expectations about agricultural innovation in order to facilitate the exchange and wise application of knowledge.

Conclusions

The report highlights several inconsistencies and disconnects across the current policy landscape. Thus the EU has approved the importation of certain foods of GM crop origin, but not approved the same GM crop for cultivation within the EU. It has an historic and current commitment to investing in plant sciences and promoting a knowledge-based bioeconomy, but neglects to use some of the advances made by research for agricultural innovation. It aims to reduce chemical pesticide use, but over-regulates alternative genetic approaches to crop protection. And the impact of its GM policy and practice is in conflict with EU global development policy.

Rapid changes are taking place in the distribution of power in agriculture worldwide, and the EU has already retreated from some world markets. A greater emphasis on crop genetic improvement technologies may be only part of the solution to this decline, and to the sustainable intensification of agriculture; but to exclude any valid tool, as EU policies risk doing, is unwise.

The European Union has much to do.

EASAC – the European Academies Science Advisory Council – is formed by the national science academies of the EU Member States to enable them to collaborate with each other in providing advice to European policy-makers. It thus provides a means for the collective voice of European science to be heard.

Through EASAC, the academies work together to provide independent, expert, evidence-based advice about the scientific aspects of public policy to those who make or influence policy within the European institutions. Drawing on the memberships and networks of the academies, EASAC accesses the best of European science in carrying out its work. Its views are vigorously independent of commercial or political bias, and it is open and transparent in its processes. EASAC aims to deliver advice that is comprehensible, relevant and timely.

The EASAC Council has 28 individual members and is supported by a professional secretariat based at the Leopoldina, the German National Academy of Sciences, in Halle (Saale). EASAC also has an office in Brussels, at the Royal Belgian Academies of Science and the Arts.

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