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COME BACK GM: ALL IS FORGIVEN!

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BACKGROUND

The genetic engineering of plants is now a well-established technology, with the first genetically modified crop plants being developed in the 1980s and commercialised in the mid 1990s. In fact, in 2008 GM crops were grown in 25 countries worldwide, including Africa (Burkina Faso, Egypt), Asia (China, Philippines, India) as well as the Americas (North, South and Central) and Europe (Spain, Czech Republic, Romania, Portugal, Poland and Slovakia) [1]. The total area covered in 2008 was 125 million hectares with four crops (soybean, maize, cotton and canola/oilseed rape) accounting for the majority of this [1]. None of these countries have reported scientifically-substantiated problems associated with the crops and it is therefore difficult to understand why many in the UK remain so resistant to a technology which has proved to be safe and profitable.

ADVANTAGES OF GM TECHNOLOGY

Humankind has been manipulating crops for many years. For example, bread wheat first appeared about 9000 years ago and has been cultivated continuously since. Unconscious selection over much of this period and scientific breeding over the past century have led to an immense range of diversity, with over 25,000 types of wheat now being represented in genebanks and germplasm collections.

Plant breeding has been highly successful in increasing crop yields and improving crop quality but also has significant limitations. Firstly, crops are immensely complex organisms. For example, the genome of bread wheat comprises about 50,000 genes. Plant breeding aims to identify the most advantageous combinations of these genes, by crossing selected lines, generating large populations of progeny and selecting these for the required combinations of characteristics ("cross the best with the best and select the best"). Consequently the production of new varieties of crop plants requires considerable investment of time (6-7 years in the case of wheat) and money as well as highly-skilled plant breeders. GM may therefore help to accelerate the production of new varieties, by precisely transferring single genes, or small numbers of genes, into current high performing backgrounds with no detrimental genetic drag from the donor genome.

However, the major limitation to the production of new varieties by classical plant breeding is the level of variation in the crop, or in related species with which it can be crossed. Genetic engineering allows the exploitation of genes from other plant species, microbes or animals, including completely new genes with new functions. For example the herbicide tolerance and insect resistance genes which are widely exploited in commercial transgenic crops are derived from microbes.

FIRST GENERATION GM CROPS

The dominant trait exploited up to now has been herbicide tolerance, which accounted for 63% of the total area of GM crops in 2008. This is followed by insect resistance (15%) and the two traits combined (called gene stacking) (22%)[1]. Other traits, including virus resistance, together have accounted for less than 1% of the total area.

Herbicide tolerance and insect resistance have resulted in massive improvements in yield and production efficiency. Furthermore, correct management practices result in substantial environmental benefits, particularly from the reduced use of insecticides on crops such as cotton.

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Furthermore, in addition to being successful in their own right, these first generation traits have been important in establishing the credibility of GM crops as components of global agricultural systems.

However, it is clear that the next generation of transgenic plants will be engineered to target a wider range of traits, including traits which are of fundamental importance for human nutrition and health in the 21st century as well as sustainable crop production.

Transgenic plants of linseed engineered to produce fish oils in their seeds, being grown under containment at Rothamsted Research
This technology will have health benefits for human consumers and environmental benefits in reducing reliance on declining stocks of marine fish (figure kindly provided by Professor Johnathan Napier, Rothamsted Research).

WHY DO WE NEED GM CROPS NOW?

There has been much recent discussion of the "grand challenges" posed by population growth, climate change and the depletion of fossil fuels. The implication of these challenges for crop production is that yields on good agricultural land must be increased and cultivation also extended to land which is currently considered as unsuitable for crop production due to environmental constraints.

Of particular importance for future production is the development of staple crops that are able to resist drought, and this includes crops grown in the UK and Europe where drought is occurring with increasing frequency. Drought tolerance is likely to be achieved by a combination of classical breeding and genetic engineering, and drought-tolerant maize produced by genetic engineering has been promised by Monsanto and other companies. Similarly, resistance to high levels of salt or other minerals such as aluminium and boron will allow production to be extended to contaminated soils in many countries where climatic factors are otherwise suitable for crop production (including parts of Australia).

The second major limitation to crop yields, after climate conditions, is infection with pests and pathogens. The insect resistance genes deployed in the first generation of GM crops have proved to be very effective in combating insect pests but fungal pathogens remain a challenging target. The success achieved by BASF in engineering resistance to blight *(Phytophthora infestans)* in potato is therefore particularly impressive. GM also offers potential solutions to other intransigent pest and pathogens including nematodes and molluscs where current control measures are very environmentally damaging.

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A third consideration is environmental and economic sustainability. Current elite crop varieties have been selected to perform well under relatively high inputs of fertiliser, herbicides and pesticides which are becoming increasingly difficult to justify. GM could play a part in transferring traits such as nitrogen fixation, improved nitrogen utilisation and durable pest and disease resistance from unrelated species into crop varieties.

DIET AND HEALTH

In the UK, Western Europe and North America many health problems result not from inadequate nutrition but from over-consumption of highly refined energy-dense foods. These foods lack sufficient amounts of dietary fibre, vitamins and minerals and are often rich in saturated fats. GM offers opportunities to produce healthier foods with acceptable properties for consumers. For example, increasing the content of fibre and decreasing the digestibility of starch in cereal products will assist in reducing the incidence of obesity and type 2 diabetes, which are projected to reach epidemic proportions by the middle of the present century. Similarly, omega-3 long chain polyunsaturated fatty acids (LC-PUFAs) (fish oils) have a range of health benefits but can currently only be sourced from oily fish. However, these compounds are not synthesised by the fish themselves but derived from marine microbes (algae and diatoms) in their diet. At present they are provided in diets for aquaculture by harvesting marine fish considered to be unsuitable for human consumption but this is not sustainable in the context of declining fish stocks. Recent work in public and private sector laboratories has led to the development of new types of commercial oilseeds which accumulate LC-PUFAs in seed oils, meaning that they can be used to replace marine fish in diets for aquaculture or consumed directly by humans.

Acknowledgements

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References

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COMEBACK GM: ALL IS FORGIVEN

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Galileo Galilei stated that all "truths are easy to understand once they are discovered; the point is to discover them". This view is central to scientific research on genetically engineered (GM) crops. This presentation attempts to cover the potential this approach has both for the UK and global food security and some of the constraints to progress. The core view advanced is that GM crops are not a panacea to achieve food security for all but an important approach that should be researched and not set aside. The context is the need for 70% more food from the current global agricultural area by 2050.

BENEFITS FOR THE UK

It is a commonly held view that the UK population can be fed without use of GM crops. This is essentially correct if food prices remain at current levels but any cost reduction GM crops can provide would benefit the estimated 30% of UK children that live in poverty. The deployment of GM crops offers a range of more certain advantages. These include improved productivity, reduced use of pesticides (PG Economics, 2003), the benefits that land sparing can provide (Green *et al*, 2005), an ability to respond to climate change issues (eg increased water use efficiency), production of functional foods and of new products including medicinal products and vaccines at a fraction of current production costs (Fox, 2006; Nature Editorial, 2009).

Consumers support EU legislation moving in the direction of reduced pesticide application. It is generally accepted that plant resistance is the method of choice to control plant pests and diseases. A key advantage is that its use requires no change to agricultural practices. An example of much needed resistance in the UK is to one of two potato cyst nematodes, *Globodera pallida* which infests most of our potato fields (Atkinson *et al,* 2008). Over 50 years of conventional plant breeding has yet to provide a cultivar that is fully resistant to it. Resistance breeding for potato has the additional limitation that not all agronomically desirable traits can be delivered in one cultivar. This is shown by cultivars marketed in the last 20 years representing only 14% of the UK seed potato market. The GM approach allows improvement such as nematode resistance to be added to a cultivar without changing its other favoured attributes. Much research has established that this basis for nematode control poses no risk to the environment. It is safe for consumers because it relies on a protein already present in our food (eg rice and maize seeds). It is similar to a natural constituent of our saliva that we all swallow continually. Use of this technology offers the additional advantage of ensuring potato crops remain on the land currently used for the crop. Movement of potato growing to other land has caused archaeological damage that concerns English Heritage.

FOOD SECURITY

The incorrect view that GM crops lack value for the poor has been exposed by the uptake of cotton with insect resistance in India. It was not introduced until 2002 but it was 81% of all cotton produced in India in 2008-9. Cotton production by that country has nearly doubled and yields have increased by over 80% (Karihaloo and Kumar, 2009). The lack of other successes in the developing world is in part the consequence of campaigns over many years against the approach. This has even forced potentially useful products from the market. As a result, innovation by public research and development of pro-poor applications has been suppressed. A strong case has been made that the EU as well as activists is responsible for much of this outcome (Paarlberg, 2008) although not all agree with that analysis (Scoones, 2008).

Plant biotechnology is now widely deployed (James, 2008) and applications should be developed for Africa (Karembu *et al*, 2009). There is a need for African nations to have the capacity to judge GM science and to adopt approaches that they consider have value for their people. Much of current effort on such crops is public not-for-profit research. This is preferable to technology being "parachuted-in" from developed economies. Cooking banana is an example crop that would benefit (Atkinson *et al,* 2003). Its sterility limits progress of conventional plant breeding but enhances GM biosafety. Banana suffers severe yield losses from a range of pests and diseases that GM approaches could counter. GM approaches have particular potential when a plant and its cross-fertile relatives lack required traits. The potential of GM crops is enhanced when several beneficial traits are provided within one variety the poor wish to grow.

CONCERNS

Extensive experience of safe GM crops suggests those who seek to limit their uptake should provide the evidence to support their views. Their problem is that the weight of scientific evidence is contrary to the anti-GM standpoint. One often expressed concern is for the environment. Risk has been exaggerated and much made of flimsy evidence. One good example is the Monarch butterfly in USA. Preliminary concern was expressed that pollen of GM maize cast on Milkweed plants killed caterpillars of this butterfly that always feed on this weed, often at field margins. This concern can now be discounted (USDA, 2004). A second issue is the consequence of gene flow from a GM crop. This risk depends on the crop, its geographical location and also the ecological value of the GM trait to any recipient plant (Stewart *et al*, 2003). For instance, gene flow may occur from potato in Peru where nearly 200 wild relatives occur some of which grow in fields. In contrast there is no risk in the UK where limited wild relatives occur and crosses in the field have never been reported. Potato is therefore a safe crop for which to develop GM technology in a UK context.

Much is made by some of

the level of concern among the UK population over GM crops. However, neutrally framed surveys show this is a declining issue and not one of the top 10 food issues of the UK consumer (Food Standards Agency, 2008). UK consumers also support the use of GM crops in the developing world. GM crops must and can have a higher food safety than many currently consumed products. However, risk can only be assessed by considering both the hazards and any exposure to them. For instance, caffeine is the hazard in coffee and the exposure is the number of cups drunk. The reality is that the risk from drinking coffee although inconsequential is very much greater than for any GM crop that would be marketed.

CONSTRAINTS

Society needs whistleblowers and critics of any technology have a role to play. However continual use of inaccurate or flimsy evidence is not in the public interest but remains unchecked largely because there is no accountability. All our contributions to any debate are framed by other issues (Herring, 2009). A humanitarian perspective has led the Vatican to support consistently GM crops as a means to enhance food security (Anon, 2009). The Nobel Laureate Norman Borlaug took a pro-science standpoint when judging them to be a second generation of the green revolution he founded. The contributions of those hostile to GM crops are also framed by other issues. Examples are the need for some non-governmental organisations to retain the high public attention level they need to generate subscriptions and a belief in other food production systems such as organic farming (Randall, 2008).

Legislation in the EU does not favour development of plant biotechnology (Atkinson, 2008). In particular it fails to recognise specifically the need for small scale field trials not tied to commercial intent. This need is accepted by the Canadian authorities (Canadian Food Inspection Agency, 2008). This is a key factor in the huge disparity between the number of GM field trials in USA (>1000 in USA in 2007 alone plus many small trials) and a total of only 496 in the EU in the period 2002-08. The EU has also failed to authorise the commercial growing of a starch potato after it passed through all its regulatory steps (German Federal Ministry, 2008). Instead of the EU supporting European technology and a knowledge economy, it has been taken to court by a major European company (BASF, 2008) for its obstructive approach.

The overuse of the precautionary principle by the EU is also evident within the Convention on Biological Diversity that controls the Cartagena Protocol (Anon, 2000; 2009). Compliance with this protocol imposes a high cost for developing world nations (De Greef, 2004) but the real risks avoided have yet to be defined. It has also not used the protocol's article 7.4 for GM products with a long history of safe use to which the precautionary approach should no longer apply. Its biosafety committee also lacks an appropriate balance of stakeholder nations and seems unable to grasp the consequences of its negative stance. Doing nothing to enhance food security is a risk to the poor (Nuffield Bioethics committee, 2004). It delays and even blocks biotechnology that may have long term benefits (Strauss *et al*, 2009). The Convention on Biological Diversity has also proven ineffective against clear and present environmental risks in the UK. One example is the alien invasive species, the Harlequin beetle. It was previously used elsewhere in the EU as a biological control agent and is now harming UK biodiversity.

Unfortunately, the UK has sometimes been slow to respond to technical advances. Examples are restrictions placed on the early motor vehicles (Anon, 2007) and milk pasteurisation. An estimated 40,000 UK citizens died of tuberculosis from 1908 until the 1930s while vested interests supported by some MPs resisted the adoption of milk pasteurisation (Phillips and French, 1999). Part of the opponents' arguments centred on considering the treatment of milk as an unnatural process. Modern parliamentarians should consider scientific evidence, identify misinformation and dismiss it. The UK needs politicians who come down firmly on the side of rightness and not expediency. They should use their influence to support the reform of EU regulation of GM trials and crops. The UK must develop a knowledge economy and use its crop science base effectively (Baulcombe *et al*, 2009). We should progress GM crops on a case-by-case basis with rigorous but not obstructive oversight on all aspects of food and environmental safety.

N.B. All text references may be obtained on the website www.scienceinparliament.org.uk

DURING DISCUSSION THE FOLLOWING POINTS WERE MADE

There is a big debate in the EU concerning this topic. One of the problems is that although the initiatives of Rothamsted and others working in this area are greatly appreciated, we also have learn as scientists to explain better, with openness, accountability, transparency and dialogue. If we look at Europe we have a massive problem there where many of the policy-making processes are considered only on a hazard-based rather than on a risk-based approach, which ignores the fact that a hazard without a target or a pathway is no risk. EU policy is strongly influenced by NGO campaign-based organisations comprising groups of activists. Hence the EU has become very risk-averse and clearly does not understand the difference between hazard and risk. The UK Government however works well on a science-based policy. Scientists are unfortunately losing the debate in the media where they need to deal with a lack of understanding of risk. Generic debates on technology are misplaced and should move on to consider specific issues, as in any other modern technology.

Greenpeace and Friends of the Earth have developed religious objections which ignore the scientific evidence and are unreliable witnesses, and when Peter Melchett was asked whether there is any evidence which would change his mind and change his opposition to GM, he responded: no, his views were definite, permanent and absolute. Opposition to GM varieties of maize, corn, rapeseed and soyabean has had a perverse effect resulting in these crops going into biofuels and bioethanol rather than being used to feed hungry people in the third world. GM is also banned in several countries as sensitivity to a pathogen could wipe out a whole crop.

The UK scientific community urgently requires scientific data on which to base future research, and although a case against trials is required to focus the debate, none has ever been provided in spite of every encouragement to do so.