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POSTNOTE

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GM in Agricultural Development

Almost 2 billion people suffer from chronic hunger and malnutrition in developing countries.[1,2] The UK funds research into genetic modification (GM) as one option for agricultural development. This POSTnote examines the potential benefits and challenges of using genetically modified crops to improve food security in developing countries.

Overview

- Investment in agricultural research has been shown to increase the value and volume of crops produced.[3]
- Genetic Modification (GM) may offer the potential to improve crop yields, through increased resistance to pests and diseases,[4,5] improved tolerance of drought and flooding[6,7] and improving resilience during storage and transportation.[8,9]
- Public funding may be required to develop GM crops that specifically benefit smallholders in developing countries.[10-12]
- There are agricultural development challenges facing developing countries that GM will not address,[13] such as access to irrigation.

Background

Global population has risen from 2.6 billion in 1950 to around 7 billion, and is predicted to rise to 9 billion by 2050. The recent Foresight report on "The Future of Food and Farming" suggested that demand for food could rise by 70% by 2050.[14] Most of this demand is likely to be from developing countries as they have the fastest population growth rates, and the highest number of people living with chronic hunger.[15] They are also more at risk from resource shortages and the effects of climate change.[16,17] The Millennium Development Goals aim to halve the number of people living with chronic hunger by 2015 and the UN Declaration of Human Rights recognises the Right to Food.[18] Pressure to increase food supply can lead to deforestation in many developing countries, exacerbating environmental degradation and climate change.[19] Increasing food supply without causing a net change in land use means increasing production on existing land. This makes agricultural development in developing countries a pressing need.[20-22]

Agricultural Development

Agriculture is economically important to developing countries: part of the definition of a developing country is having a majority of the labour force working in agriculture.[23] One-third of Africa's GDP comes from agriculture, and two-thirds of the labour force is employed in it.[24] Most farmers in developing countries work on smallholdings of less than two hectares.[25] The optimal places to improve crop yields are areas such as sub-Saharan Africa, where 96% of farms are rain-fed,[26] with low inputs in terms of soil improvements or fertiliser.[27] While the focus of this note is on the role of GM in agricultural development, other approaches are available, and these are outlined in Box 1.

GM and Developing Countries

Crops and Countries

GM is a plant breeding technique that has been used commercially for 17 years (POSTnote 386). GM crops are currently grown in only a few developing countries. However, these countries tend to grow them extensively:

- In 2010, 48% of GM crops were grown in developing countries.[28]
- 8 of the top 10 countries growing GM crops commercially are developing countries, led by Brazil and Argentina.[28]
- India and China grow large amounts of Bt cotton, with an estimated 90% of India's cotton crop being GM.[29] Bt cotton is cotton that has been modified to produce a protein from the bacterium *Bacillus thuringiensis* (Bt) (POSTnote 386), which acts as an insecticide for specific groups of insects.

Potential benefits of GM

GM offers the potential to improve crops in ways that are not possible through conventional breeding, by introducing traits that plants do not possess, such as herbicide tolerance or pest resistance.[4,5] GM often has the same goals as conventional plant breeding. There are many potential GM crop improvements, although most are still at early stages of development. Examples include crops:

- That can grow in marginal or undesirable conditions, for example, saline tolerant rice.[30]
- That can better tolerate drought or flooding, helping mitigate the effects of erratic weather patterns.[6,7]
- That have improved micronutrient content, for example Vitamin A enriched “Golden Rice” (POSTnote 367).[31]

However, there are also potential environment and health risks associated with the use of GM crops (see page 4).

Box 1. Approaches to Agricultural Development

There are many approaches to agricultural development. These can be split into two broad categories: production agriculture and agroecology. These approaches can both be used to promote desirable crop characteristics, with different methods having variable success depending on individual circumstances.

Production Agriculture

Production agriculture seeks to improve inputs into agriculture. This includes the use of fertilisers and pesticides, and developing improved seed. Biotechnology approaches are based on improving crops at seed level. Techniques include:

- Marker Assisted Selection, a widely used technique that speeds up plant breeding by analysing the plant’s genome to see if a particular trait has been bred into a plant or not.
- Tissue culture grows whole plants from a single cell or clump of cells in an artificial growth medium. This allows thousands of identical plants to be grown from one parent plant, so plants can be replicated faster than by seed production.
- GM, which enables the direct transfer of genes from one organism to another, including genes between sexually incompatible species (for example, from bacteria to plants) (POSTnote 386).

Agroecology

Agroecology, also referred to as ‘sustainable agriculture’, uses natural sciences to understand elements of agro-ecosystems, such as soil properties and plant-insect interactions, as well as social sciences to understand the socio-economic and cultural effects of farming practices. It is particularly applied by smallholder farmers, as it focuses on improving local food production. The UN Special Rapporteur on the Right to Food states that small-scale sustainable agriculture would double food production in 5-10 years in areas where most hungry people live.[32] The International Assessment of Agricultural Knowledge, Science and Technology for Development report “Agriculture at a Crossroads” argues that export-oriented agriculture is unsustainable, and there is a need for increased local food production.[13]

Biosafety Regulation and Legislation

International and national biosafety legislation regulates the use of GM crops. There are 162 countries who are party to the Cartagena Protocol on Biosafety to the United Nations Convention on Biological Diversity, which governs the safe handling, transport and use of GM organisms.[33] The Cartagena Protocol requires countries wishing to grow GM crops commercially to establish a regulatory framework for approving new crops, including conducting thorough safety testing. The protocol has been criticised by pro-GM scientists as overly cautious, due to liability clauses that hold technology developers responsible for environmental damage.[34]

National regulation is not well developed in many developing countries, and is in various stages of progress through national legislatures. In Africa, only 3 countries (South Africa, Egypt and Burkina Faso) grow GM crops commercially. Kenya recently enacted their biosafety law, but is not currently growing GM crops commercially. Others, including Uganda and Nigeria are conducting field trials of GM crops, but lack the necessary legislation for commercial distribution. In Uganda, the National Agricultural Research Organisation hopes that developing GM crops will help drive legislation, by encouraging the Government to act as crops reach commercial readiness.

Building a regulatory infrastructure with appropriate input from stakeholders can generate trust in regulatory institutions.[35] This is a major challenge in most developing countries.[36,37] Using a broad precautionary approach could help to deal with uncertainties and avoid reducing complex issues to a simplistic risk assessment.[38] Some attempts to include the general public and NGOs in the development of regulation have been criticised by scientists and industry as slowing down innovation.[35] However, organisations such as Genewatch contend that it questionable whether any regulatory system can provide sufficient confidence in the safety of GM crops, and the ability to recall them if something goes wrong.

Trade

Most food trade is regional, and most developing countries are net food importers. Developing countries could benefit from ensuring that their regulatory frameworks deal with crop imports, as well as exports. Developing countries also face specific challenges when considering introducing GM crops to domestic markets. For example, when trying to ensure consumer choice over consumption of GM crops, labelling the GM status of products is problematic where illiteracy is common or trade involves informal markets.[35]

Developing countries’ views on whether or not to plant GM crops could be influenced by the views of their international trading partners.[39] For example, some African countries could be put off growing GM crops because of the negative public perception of GM in some European countries, which are Africa’s biggest trade partners. For example, Egypt and South Africa stopped development of a Bt potato for fear of losing European export markets.[40] Additionally, the EU insists on each GM crops being approved through the European Food Standards Association (EFSA), even if it uses a gene that has previously been approved (POSTnote 386). This means that only large biotechnology companies can afford the high costs of obtaining EFSA approval for the sale of GM crops to the EU.[41-43]

Given the globalised nature of food production, it is possible that a GM crop could be legally produced in one country, and sold in another where production has not been approved.[39] Segregating GM and non-GM crops is going to be a particular challenge for developing countries, most of which lack the necessary facilities to store existing produce, let alone keep two supply chains separate to minimise cross-contamination during storage, processing and transport.[44]

GM and Intellectual Property

Most developing countries currently lack the capacity to develop new gene sequences for use in GM crops, and rely on genes developed elsewhere. Organisations like the African Agricultural Technology Foundation (AATF), which acts as a broker to facilitate the transfer of royalty free biotechnology for research to benefit African smallholders, are important for enabling this process. Increasing research collaborations, and establishing more public-private partnerships, could enable the development of new crops (Box 2). However, Genewatch argues that GM crops will be patented even if their development is publicly funded, meaning companies that licence the patents will control crop markets.

> Box 2. Public-Private Partnerships
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> The public and private sectors both have specific areas of expertise for promoting the development and distribution of GM crops. Public organisations such as the Consultative Group on International Agricultural Research (CGIAR) and AATF could look at partnering with commercial organisations to bring research products to market. The private sector is often best placed to carry out seed production and distribution, but local companies need to be improved in most developing countries, as they lack the infrastructure to support these improvements. An additional concern is how benefits from the sale of seeds will be channelled back into publicly-funded research.

Funding GM Research

Investment in GM from the public sector is small when compared to private sector funding.[45] Scientists in developed and developing countries think public sector research will be needed, at least initially, for the development of GM crops that address the specific needs of developing countries.[10-12] This is because many crops grown in developing countries have limited commercial potential, as farmers have limited resources for purchasing new seed every year.

Almost all major international aid agencies and donors are funding GM research to some extent. The Bill & Melinda Gates Foundation has committed about $2 billion to global agriculture and nutrition programmes, with about 6% ($120 million) of this being spent on research into GM.[46] The current Department for International Development (DFID) policy on GM research is that if GM is to be a useful tool for the future, research needs to be taking place now. DFID usually funds research into GM indirectly, primarily through funding the CGIAR (Box 2), a global umbrella organisation coordinating agricultural development research and funding. DFID provides around 8% of the CGIAR's $800 million a year operating budget. Around 2% ($16 million) of the CGIAR budget is spent on GM research.

GM Crops for Smallholders

Current GM research has primarily focused on global commodity crops such as maize and soya. This has produced GM crops that could be grown by smallholders, but uptake has been slow. Other vital smallholder crops including millet, sorghum, cassava and cowpea, have not been a focus for seed developers.[47] These crops have the potential for yield and pest and disease resistance to be significantly improved, as so little work has been done on them previously (Box 3).[47] Smallholders need to be able to choose whether or not they will use GM. Ensuring smallholders have access to unbiased information about GM crops is a major challenge. Organisations may have specific agendas regarding the adoption of GM, and may highlight information that is most beneficial to them. Government agricultural extension services, which could be sources of advice to smallholders, are often chronically under-resourced.

> Box 3. GM Crops for Smallholders
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> Current Crops: Bt Cotton
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> Bt cotton is the only GM crop grown commercially by smallholders.[48] It is officially grown in China, India, Pakistan, Colombia, Egypt, Burkina Faso, and is grown unofficially in other countries.[49] Cotton growers have adopted Bt cotton because of the increased income they receive from improved yield and reduced pesticide use.[50] There is evidence that this reduced pesticide use can also improve biological pest control.[51] Some farmers have reported negative consequences where yields have decreased due to a secondary pest or the increase in yield was not sufficient to cover the increased cost of the seed. However, assessing these benefits is difficult, because of variation in how yields are monitored and reported, as well as difficulties in assessing how well farmers adhered to the guidance associated with planting GM seed.[48,52]
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> Potential Crops: Maruca-resistant Cowpea
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> Smallholders in West Africa identified Maruca pod borer (an insect pest) as a major problem reducing cowpea yields. Cowpea is a major subsistence crop across Africa. USAID, the Rockefeller Foundation and AATF, in collaboration with Monsanto and local researchers, have used the Bt gene to develop a Maruca-resistant cowpea that is undergoing field trials in Nigeria and Burkina Faso. Maruca-resistant cowpea is expected to be commercially available in 2017.[53]
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> A Possibility: Cassava?
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> Cassava could be developed as a "pro-poor" biotechnology because it is a key subsistence crop propagated through planting stem cuttings, and can be distributed without controls by seed producers or distributors. It is currently underdeveloped with regards to nutrient content and yield.[54] Cassava Brown Streak Disease is causing large crop losses across sub-Saharan Africa. GM is currently being researched as a method to bring the disease under control by the VIRCA (Virus Resistant Cassava for Africa) project, a collaborative program between the Donald Danforth Plant Science Center, USA, the National Crops Resources Research Institute, Uganda, and the Kenya Agricultural Research Institute.

In some countries, e.g. India, China and the Philippines, there are instances of GM crops being grown 'illegally'. This is done by crossing GM seed with local varieties, rather than buying 'official' GM seed from a distributor. This is primarily done by smallholders who cannot afford the premium for GM seed, or where GM seed has not been approved for sale in their country.[55] It poses a particular problem for seed producers where liability clauses in biosafety legislation hold the original technology producers responsible for GM seed, even if it is used in ways that were not recommended. Appropriate regulatory infrastructures and fair pricing of GM seed could help to mitigate this.[55]

Seed saving

Saved seed (collecting seed from crops to replant the next year) is an important resource for smallholder farmers.[56] One of the major criticisms of GM crops for smallholders is that for many commercially available varieties farmers need to purchase seed every year in order to maintain yields.[54] As much of the current research on GM crops for developing countries is publicly funded, donor agencies are starting to require GM projects to allow farmers to save their seed. For example, all GM projects being funded by the Bill & Melinda Gates Foundation require the project to allow farmers to save their seed.

Comparing GM and non-GM Strategies

The Risks of GM

There is a polarised debate over the use of GM crops. There are numerous studies examining the evidence for benefits[50,57,58] and disbenefits[59-62] of GM, as well as the extent to which this evidence is sufficient to fully assess the risks of GM.[63] Environmental risks include the unintentional crossing of GM crops with non-GM varieties.[64] Field trials have shown that this is possible in closely related species.[65,66] There is no evidence in peer-reviewed scientific literature showing a link between commercially available GM crops and a risk to human health,[8,9] but there are always uncertainties. There is also some evidence of GM crops causing environmental damage,[67] although proponents claim this is limited to pre-commercial crops, and the ecosystem recovered within a few years.[68] Because of the diversity of agricultural systems in developing countries, it is difficult to generalise about the possible risks and benefits of GM crops. Any crop should be thoroughly assessed with regard to the technical, ecological, and economic, as well as the social risks posed in different contexts.[35,38,48,63] Other solutions, including infrastructure, policy and institutional solutions, all need to be evaluated in order to determine if GM has a contribution to make to an agricultural development issue.[52]

Lead Time to Market

There is a lack of peer reviewed evidence of the time taken to develop new GM crops. There is general agreement among scientists that developing new gene sequences for GM crops can be done relatively quickly, although this varies based on the complexity of the new trait being created. Complex traits such as nitrogen fixation and salt tolerance require multiple genes to be expressed, and so take longer to develop. After the required gene sequence is developed, it can take 3-5 years to get the desired genetic sequence into existing local varieties. Then the new GM variety has to satisfy all the regulatory requirements for GM crops (up to 10 years or more). Finally, it can take 2-5 years to produce all the seed required to distribute to farmers. In total, the time taken to get GM crops to market can be considerable.

GM as a Component of Agricultural Development

GM is not a single solution for all the problems facing agriculture in developing countries. It has success in specific cases against particular problems (Box 4). Current commercial varieties only combat problems with some pests and diseases. However, wider agricultural development issues also need to be addressed, for example:

- Crop storage and getting crops to market before they spoil. The Indian Government estimates that up to 40% of fruit and vegetables rots in the fields or on the way to market, and grains are also rendered inedible because of a lack of rodent-free cool storage.[69] A lack of paved roads can cause food to spoil during transportation, particularly if it needs to meet international quality standards.
- Ensuring mechanisms are in place to allow benefits to reach poor and marginal famers, for example giving farmers access to crop insurance, which will protect them financially in the event of adverse weather conditions.[70,71]

There are also other agricultural improvements where GM could play a role, but other strategies may provide more cost-effective interventions. For example:

- Improving access to irrigation, which alone could increase African agricultural yields by 100-400%.[23] GM could develop plants that use water more efficiently, but improving access to irrigation through infrastructure development could be quicker and more cost effective.
- Improving soil fertility through increasing soil organic and nutrient content, as all crops require uptake of soil nutrients to achieve the best yields, even if they are modified to fix nitrogen, or have improved photosynthesis.
- Increasing resilience to extreme weather events, such as drought and flooding could be achieved by introducing drought or flooding tolerance into plants, or through improved agronomic practices such as ridge-and-furrow planting and mixed cropping.

Box 4. Case studies on the need for GM approaches

Choosing Not to Use GM

There are a number of projects looking at improving food production, primarily in Africa and South Asia that have chosen not to use GM to improve crop varieties. Scuba Rice, a flooding-tolerant rice developed by the International Rice Research Institute (IRRI) is a conventionally bred crop, using marker assisted selection. IRRI chose not to use GM because there are flooding tolerant rice varieties, just not in the varieties preferred by farmers. Therefore IRRI could introduce the flooding tolerance to the farmers' preferred varieties through conventional breeding, avoiding the regulatory requirements of GM crops. HarvestPlus, an organisation developing staple crops with higher micronutrient availability, also does this primarily through marker assisted selection for the same reason.

Choosing GM

GM offers the potential to improve crops in ways would be substantially more difficult, or even impossible, to achieve through conventional means. The Sustainable Agricultural Research for International Development project (majority funded by DFID), included a project to use GM to prevent nematode infestation (a type of root pest) in bananas that is about to move to confined field trials in Uganda. Bananas are especially important in Uganda, where it is estimated that the average person consumes 200kg of banana annually.[72] Because bananas are sterile, they are particularly difficult to improve using conventional methods.[73] Experts believe that GM provides an opportunity to improve bananas in 5-10 years, at least half the time of conventional breeding.

Endnotes

For references, please see http://www.parliament.uk/documents/post/postpn412_gm-in-agricultural-development-references.pdf

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