Agricultural Biotechnology's Potential Contribution to Global Food Security and Stewardship of the Earth's Resources**

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Summary

Over the coming decades, food and agricultural production systems must be significantly enhanced to respond to a number of transformative changes. These changes include a growing world population, increasing international competition, globalization, increasing meat consumption in developing countries, and rising consumer demands for improved food quality, safety, nutritional content, convenience, and provenance. New and innovative techniques for improving the efficiency of the global agriculture sector will be required to ensure an ample supply of healthy food. From the food deserts of inner cities to the infertile areas of many regions, access to a healthy diet remains elusive for many. Dramatic increases in the occurrence of obesity, cardiovascular disease, diabetes, cancer, and related ailments in more-affluent countries are in sharp contrast to the chronic malnutrition in many lower-income countries. Both sets of problems require a modified food supply, and the tools of biotechnology, while not the sole solution, have a significant role to play. Agricultural biotechnology, including advanced plant breeding and genetic engineering (GM crops), has already helped farmers around the world boost their productivity and grow crops in more ecologically healthy fields, while allowing much more efficient use of resources. This technology allows reduced tillage, which cuts down on greenhouse gas emissions, water runoff, soil erosion, and fuel consumption. This technology also allows improved pest control, increased yields on existing acreage, and reduced pressure to convert forests and wildlands into farmland. However, the technology's potential may remain unfulfilled if such barriers as disproportionate and nonrisk-based regulatory regimes, effective disinformation campaigns, and lack of resources prevail.

Current realities

The ultimate grand challenge of our times is the sustainability of the biosphere and our place in it. Can we learn how to meet our needs today without compromising the ability of future generations to meet theirs? With the 7 billionth member of humanity having joined the planet, achieving global food security sustainably is the single most important issue facing civilization and, by implication, the planet in the next 30 years. To meet the world's needs by 2050, it is estimated that 70% more food must be produced from less land and fewer inputs, (e.g., using less water, energy, fertilizer, and chemical pest controls). The inequities between more- and less- affluent countries must be addressed using technologies that are scalable across these economic imbalances. Of immediate concern is the state of current global food reserves. In 2012, the United Nations issued an unprecedented warning about the state of global food supplies. The U.N. noted that failing harvests in the United States, Ukraine, and other countries eroded global food reserves to their lowest level since 1974, when the world's population was much lower. World grain reserves are so dangerously low that another year of severe weather in food-exporting countries could trigger a major hunger crisis by the end of 2013. Clearly, unprecedented needs require innovative solutions.

Scientific opportunities and challenges

From a basic nutrition perspective, there is a clear dichotomy in demonstrated need between different regions and socioeconomic groups, the starkest being injudicious consumption in more-affluent regions and under-nourishment in less-affluent countries. Both extremes are forms of malnourishment, one resulting from inadequate supply and the other, in many but not all instances, from imprudent choices often influenced by economic considerations. Plant-based products comprise the vast majority of human food intake, either directly or indirectly through animal feeds, irrespective of location or financial status. In some cultures, either by design or default (e.g., as a result of poverty) plant-based nutrition comprises virtually the total diet. Thus, significant nutritional improvement can be achieved via modifications of staple crops. Ingo Potrykus' Golden Rice is a seminal example of this contention. Incorporation of beta-carotene into rice cultivars and widespread distribution of this "packaged technology in the seed" could prevent 1 million to 2 million deaths each year by alleviating vitamin A deficiency. Yet, despite being under consideration for more than a decade and subjected to a barrage of risk assessments, it is still awaiting release from regulatory purgatory. One has to ask what conceivable environmental risks could possibly result from Golden Rice that would offset the benefit of preventing millions of agonizing deaths from malnutrition.

Of the 17 million farmers who grew biotech/GM crops in 2012, more than 15 million (nearly 90%) were in developing countries and, for the first time, developing countries grew more of the global biotech crops than industrial countries (52% versus 48%). Biotechnology can speed conventional breeding programs and may offer solutions where conventional methods fail, which is beneficial for growers, consumers, and the environment. The benefits experienced by larger-scale farmers in both industrialized nations and less-affluent countries are already considerable. Research by Brookes and Barfoot showed that from 1996 to 2011, biotech contributed to increasing crop production valued at $98.2 billion and reduced the environmental pesticide footprint by more than 15% by removing 473 million kilograms (active ingredient) of pesticides from the environment. Insect-resistant maize also has a collateral effect: less insect damage results in much less infection by fungal molds which in turn reduces mycotoxin contamination, a serious health hazard. Likewise, insect-resistant Bt maize has led to cumulative benefits over 14 years of between $3.2 billion to $3.6 billion with $1.9 billion to $2.4 billion of this total accruing to non-Bt maize growers through a "halo" protective effect. In addition, there was a reduction in carbon dioxide emissions in 2011 alone of 23.1 billion kg, which is equivalent to taking 10.2 million cars off the road. A 2005 paper from the Royal Society suggested that intensive high-yield farming on less land is better for wildlife than "wildlife friendly" farming. Through increased yields, biotech is contributing to conserving biodiversity by saving 108.7 million hectares of land from being converted to agricultural production (James, 2013). In addition to the large commodities, the technology has also helped some specialty crops. Virus-resistant papaya developed using biotechnology saved the industry in Hawaii as no natural resistance exists in the cultivated varieties other than via biotechnology; the use of new varieties has also helped organic growers by reducing the reservoir of virus in plants from which insects transmit the disease. A similar scenario may be needed to save the Florida citrus industry and the California wine industry from refractory pathogens for which there are no known effective and sustainable control systems.

Commercialization of biotechnology products should be just another step in a long history of human interaction with nature to meet societal needs and, as such, the same parameters of risk-based assessment should apply. Genetic modification through breeding has a long history of safe utilization for crop improvement, and modern biotechnology simply extends those benefits through more precise methods. Biotechnology offers an efficient and cost-effective means to produce high-quality food, feed, and fiber, as well as a diverse array of novel, value-added products. Unfortunately, disproportionate regulatory burdens placed on crops developed via biotechnology force reliance on older, less effective, and unsustainable crop improvement and production systems that will inevitably have a negative impact on food security. One example is the Fortuna potato that contains two genes from a wild relative that confer robust resistance against late blight disease, a $5 billion problem, obviating the need to spray with fungicides, including the organic-approved copper sulfate. Yet its developer is abandoning the European Union as it sees little hope of winning regulatory approval for Fortuna despite the potential benefits to growers and the environment. While farmers in the E.U. can afford, and continue to utilize, fungicides, low-input farmers with few other alternatives could greatly benefit from crops that are genetically superior and deliver disease resistance traits. Erecting barriers to the development and commercialization of the new technologies and innovative methods to improve crops will instead ensure that less productive and more environmentally damaging practices will expand inexorably to meet food demands.

Policy issues

- **Technical Complexities:** Technical and translational challenges must be overcome to enable introduction of desirable traits. Adequate resources are needed to ensure cutting-edge science can be applied to crop improvement. In addition, mechanisms should be put in place to facilitate translation by anticipating the downstream development, deployment, and commercialization requirements.

- **Globalization & Intellectual Property:** There is a negative impression of ownership of intellectual property in seed technologies and perceived enhancement of corporate power with possible negative impacts on employment or small farms. Innovation cannot occur without recoupment of investment. Mechanisms must be in place to reduce intellectual property barriers, improve commercialization strategies, and facilitate the transfer of advantageous technologies.

- **Liability:** There are unreasonable expectations of prevention of adventitious presence (i.e., unintentional appearance of foreign material in a product) that is nonproportional. Coexistence between different production systems requires reasonable tolerances and thresholds to be proportionate and workable.

- **Regulatory oversight:** Worldwide regulatory regimens are asynchronous and not science-based. Regulatory frameworks must be developed that ensure adequate protection of the consumer and the environment while not stymieing innovations that enable deployment of beneficial technologies.

- **Consumer acceptance:** There has been an effective misinformation campaign around biotechnology and the agenda has been ceded to those with alternate intent. A more effective communication strategy must be developed with scientists setting the agenda using evidence-based science and appropriate context. Trusted sources must be used to deliver the message.

Ultimately, resources are finite and true sustainability can come only from an enlightened philosophy that promotes the development of resource-enhancing technologies.

References

Brookes, G., and Barfoot, P. (2012). Global impact of biotech crops: Environmental effects, 1996–2010. *GM Crops and Food: Biotechnology in Agriculture and the Food Chain* 3:129 – 137.

Eliasson, J. (2012). Deputy Secretary-General's Remarks to the State of the Planet 2012 Conference, at Columbia University, New York City, 11 October 2012.

James, C. (2013). Global Status of Commercialized Biotech/GM Crops: 2012. ISAAA Brief No. 44. International Service for the Acquisition of Agri-biotech Applications, Ithaca, N.Y.

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Debate Summary

The following summary is based on notes recorded by the ISGP staff during the not-for-attribution debate of the policy position paper prepared by Dr. Martina Newell-McGloughlin (see above). Dr. Newell-McGloughlin initiated the debate with a 5-minute statement of her views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Dr. Newell-McGloughlin. Given the not-for-attribution format of the debate, the views comprising this summary do not necessarily represent the views of Dr. Newell-McGloughlin, as evidenced by her policy position paper. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate Conclusions

- If the significant benefits provided by genetic modification technologies to agriculture and crop development around the world are to continue, it is critical that the unfavorable perceptions of these technologies held by the public and policy makers be changed by effectively providing unbiased, credible information.

- Extensive data exist regarding improving food production output via genetic modification compared with previous production technologies and this knowledge has contributed to making genetically modified (GM) foods safer and more sustainable. However, regulation of genetic modification technologies is significantly more stringent than regulation of previous technologies, creating a barrier to development and use of genetic modification technology.

- The precautionary principle, which guides approaches to food technologies in Europe, has a negative impact on the use of genetic modification technologies worldwide. Risk-based approaches are better suited to technologies related to genetic modification.

Current realities

Numerous mistakes were made when genetically modified (GM) foods were first developed on a large scale. Errors were identified in (i) the products developed, (ii) the economic decisions made, and (iii) the marketing and communication strategies pursued. One of the first genetically modified products developed, the 'Flavr-Savr' tomato, involved a gene being added to a tomato variant that was lacking in taste. The resulting product was very limited in its success. Additionally, rather than focusing on the existing market for fresh tomatoes, there were attempts to bypass this market, which had a negative effect on sales.

Particular consideration was given to errors made regarding messaging during the development of GM products. Neither scientists in academia nor those in the private sector adequately engaged with other stakeholders who had an interest in genetic modification (e.g., NGOs and special interest groups). It was not imagined that these groups might have concerns different from those foreseen by industry or researchers. Failure to include relevant stakeholders during the GM crop development process led to countless difficulties for the acceptance of GM foods.

Technologies developed prior to biotechnology have either been very minimally regulated or regulations were introduced at a later stage once risk-assessment processes were better understood. Biotechnology, on the other hand, has considerably more stringent regulations than previous technologies. It was suggested that this discrepancy is incongruent with the real issues and that the regulation of biotechnology goes beyond what is necessary.

The extent to which concern for GM products relates to apprehensions about the strength of multinational corporations, rather than the technology itself, was discussed. Often, stakeholders are concerned not simply with the safety level of a specific technology, but with issues such as globalization and ownership of intellectual property.

The general population was viewed as having a limited understanding of the history of hybrid crops and breeding techniques. Although plants have been crossbred for many centuries (and thus essentially genetically modified), it is often assumed by the public that the first time genetic modification has occurred is in the context of modern technologies. It was further noted that in a recent Eurobarometer survey, a large percentage of respondents believed that crops that were not genetically modified did not contain genes. Concern was expressed about the impact of these incorrect assumptions.

Mistrust of genetic modification technologies in sub-Saharan Africa, both on the part of consumers and politicians, was highlighted. It was suggested that this resulted in large part to a history of unsafe products (e.g., peanuts contaminated with toxins) being delivered to Africa from more-affluent regions as part of aid programs designed to improve food security. It was further noted that considerable damage was wrought by "Western" plant varieties being introduced into Africa without correct training and education, and that these mistakes have added to mistrust of new technologies. However, genetic modification technologies have already been applied on a large scale in more-affluent regions with no food safety issues resulting from the consumption of GM foods. For this reason, concerns that Africans are being given an unsafe or lower-quality product are unfounded. It was further suggested that concern about genetically modified organisms (GMOs) in sub-Saharan Africa is the fault of Europeans who have spread fears about the safety of GMOs.

It was suggested that there is a level of hypocrisy in European attitudes toward GMOs. Although there is strong reluctance to use biotechnology in crops or animal production, many enzymes and flavors that are part of foods, or used in the production of foods, are developed using GM recombinant fermentation processes (e.g., French cheeses are made with genetically engineered enzymes). The use of genetic modification in Europe is therefore not unprecedented, and indeed many farmers are interested in utilizing GM crops. However, concern from politicians about a potential public backlash prevents wider utilization of these crops.

One example of a success is the role of genetic modification technologies in saving the papaya industry in Hawaii. Ringspot virus, to which papaya has no natural resistance, was endemic in Hawaii and destroying papaya farming. Using biotechnology approaches, a papaya resistant to ringspot was engineered. Once this was crossbred with papayas in Hawaii, ringspot ceased to be a problem and the industry was revived. The organic papaya industry was helped by association, since levels of ringspot diminished overall.

Hundreds of scientific studies have found that genetic modification technologies may be safer and have lower environmental impacts than other food production methods. It was suggested that this is due to stringent regulations around genetic modification as well as the concentration of scientific expertise in this area. Although a large number of studies have confirmed the safety of genetic modification, this information is rarely widely publicized. While genetic modification can bring many benefits, caution was expressed against viewing this technology as a panacea, since it is simply one of many tools that can be used in efforts to reduce food insecurity.

Of all the farmers that are growing GM crops, approximately 90% are in less-affluent countries. It was suggested that the introduction of this technology in those nations has provided farmers with greater income streams and thus increased economic freedom. India was identified as a country that has had considerable success with the introduction of GMOs. When Bt cotton (a pest-resistant cotton plant containing the gene for Bt toxin) was first introduced, it was not appropriately adapted for an Indian context. However, once bred with indigenous cotton, Bt cotton became widespread in India. India has not unreservedly embraced GM technologies. Recent attempts to allow Bt brinjal to be grown in India were dismissed by the Indian Supreme Court on the grounds that the GM fruit would not be accepted by consumers.

Scientific opportunities and challenges

Biotechnology provides numerous opportunities for food production, in part because considerably more is known about this technology than previous production processes. There is a risk that excessively high barriers to entry will lead to relying on production systems that are both less safe and less sustainable. A challenge, therefore, lies in ensuring that the benefits of biotechnology can be widely realized.

Since individuals are considerably more likely to respond to messages invoking fear than they are to messages that are positive, communication issues present significant challenges for genetic modification technologies. Given that negative campaigning about genetic modification is so fervent, the challenge to communicate positive messages about GMOs is particularly great. An opportunity may lie in using stories and examples (e.g., how genetic modification saved the Hawaiian papaya industry) to explain the positive aspects of genetic modification technology.

The various challenges related to the labeling of GM products were considered. It was noted that if everything involved in the production of a crop was put on a label (e.g., herbicides, pesticides) consumers would become extremely concerned, since surveys suggest that labels are regarded as warnings against something negative. The prohibitive costs associated with labeling were also noted, in part because of the complexities of tracing each ingredient in a product back to the initial source.

While there was general consensus that safety concerns about genetic modification were unfounded, questions about environmental risks (e.g., risks associated with the spread of introduced genes) were raised. In the process of introducing traits into a plant, super weeds might be created via gene flow. It was countered that this issue can be mitigated through effective crop management, and that indeed the same risks exist with older breeding techniques. Given that genes will always flow between different crops, control management systems are critically important.

Over-reliance on biotechnology could lead to a system of monocultures that is not sufficiently resistant to change. While it was acknowledged that genetic modification does lend itself to the development of monocultures, it was suggested that sensible approaches to risk assessment could prevent this.

When adopting GM crops, an important challenge lies in ensuring the variety of crops used by farmers are adapted to local environments to mitigate any safety issues and to ensure that the plants are best able to thrive. The provision of adequate training and resources through extension specialists and the development of production management systems are key to achieving this goal.

The opportunities genetic modification technologies provide in the area of postharvest management were discussed. Traditionally, genetic modification has been focused on changing aspects important during production (e.g., pest resistance, herbicide resistance). There is potential, however, to deploy this technology to make changes to postharvest characteristics (e.g., the length of time a fruit or vegetable stays fresh after harvest).

Developing such technologies will provide opportunities to considerably reduce the amount of food that is currently wasted postharvest.

As an example, fungal contamination has traditionally been a considerable postharvest concern. With GM crops (e.g., Bt maize), however, a significant reduction in mycotoxin contamination has been demonstrated, since it is far more difficult for insects (e.g., corn worms) to burrow and create holes that fungal spores can use to enter the corn kernel. A second benefit associated with GM crops is the potential to extend the shelf life of products (e.g., down-regulation of the enzyme polygalacturonase), which would aid in decreasing the amount of fresh produce that is lost between the time it is harvested and the time it appears in markets.

There is a risk in promoting GM crop production, particularly in countries where genetic modification technologies have been less readily accepted. However, a failure to promote and introduce these technologies will result in the continued reliance on older, less safe, less sustainable production systems.

Policy issues

The question of how progress might be made on the use of genetic modification in Europe was raised. There was agreement that the precautionary principle, which defines Europe's approach to new technologies, is undesirable since it forces a reliance on older technologies rather than promoting progress. The policy environment regarding new technologies currently is an obstacle in efforts to improve food safety and security.

Although there was agreement that approaches to food technologies need to be risk based, the extent to which it is realistic to expect Europe to completely alter its assessment systems was questioned. The structure of European legal systems support the use of the precautionary principle and it is therefore difficult to expect this approach to food technologies to change rapidly. However, there are many inconsistencies in European Union regulation that contradict this point of view (e.g., GMOs are already used in certain food production processes).

Questions were raised regarding challenges relating to intellectual property for farmers using GM crops in less-affluent countries. There was concern that there might be a level of unrest if farmers did not have a sense of ownership over their crops. It was noted that universities in the U.S. are running programs related to public intellectual property both in the U.S. and in less-affluent countries. Although it was acknowledged that large corporations initially own the intellectual property from GM products because of the high costs of developing those products, it is extremely important that farmers have a stake and are able to work in conjunction with large corporations.

It was suggested that the implementation of genetic modification technologies must be considered from multiple perspectives rather than simply from scientific viewpoints. It was questioned whether the adoption of certain GM products (e.g., GM salmon that matures twice as fast) might have negative effects on smaller industries that rely on non-GM versions of products. Conversely, positive effects, (e.g., the health improvement of those whose incomes increase) also require consideration.

A key factor in gaining consumer trust regarding genetic modification technologies is to increase levels of transparency. Labeling was considered as one method that might contribute to more transparency. It was recommended, however, that all labeling should be based on risk analysis and that labeling a product based on the process by which it is made would be a problematic precedent.

Discussion focused on the best ways to work with policy makers from around the world to alter perceptions toward genetic modification technologies. Because of historic precedents (e.g., being sent food that was contaminated with toxins), many less-affluent countries are reluctant to adopt technologies that are advocated by more-affluent countries and policy makers may campaign against these products to appeal to public opinion. One way to counter this trend might be to talk to policy makers individually and demonstrate that genetic modification technologies are also widespread in more-affluent countries (e.g., the U.S.).

The question of who is able to provide credible information to both the public and policy makers about genetic modification technologies was raised. Large corporations, though often integral to genetic modification technology development, are not best placed to provide such unbiased, credible information given their financial interests in GMOs. It was noted that opinion makers in various regions around the world are the most appropriate conduits for providing information, since they have credibility with the wider population. If these individuals are provided with accurate information about genetic modification, this knowledge is more likely to filter down appropriately. One potential way to communicate positive information about genetic modification is to provide stories where GM crops have created positive change.