

## Biotechnology and Food Systems in Developing Countries<sup>1</sup>

C. Peter Timmer

*Development Alternatives, Incorporated (DAI), Bethesda, MD 20814*

**ABSTRACT** Even in a world with adequate food supplies in global markets, which is the situation today, biotechnology offers important opportunities to developing countries in four domains. First, many agronomically hostile or degraded environments require major scientific breakthroughs to become productive agricultural systems. Few of these breakthroughs are likely to be achieved through traditional breeding approaches. Second, biofortification offers the promise of greater quantities and human availabilities of micronutrients from traditional staple foods, with obvious nutritional gains for poor consumers, especially their children. Third, many high yielding agricultural systems are approaching their agronomic potential. Radically new technologies will be required to sustain productivity growth in these systems, and only modern genetic technology offers this hope. Finally, many cropping systems use large quantities of chemical inputs, such as herbicides, pesticides and fertilizers that can be unhealthy for people and soils alike. Biotechnology offers the potential to reduce the need for these inputs in economically and environmentally sustainable ways. Applying these new technologies to society's basic foods raises obvious concerns for both human and ecological health. For some, these concerns have become outright fear, and this has mobilized a backlash against genetically modified foods in any form. These concerns (and fears) must be addressed carefully and rationally so that the public understands the risks (which are not zero) and benefits (which might be enormous). Only the scientific community has the expertise and credibility to build this public understanding. *J. Nutr.* 133: 3319–3322, 2003.

### *Biotechnology and Food Systems in Developing Countries*

The genetic revolution is altering the way agricultural scientists think about even traditional crop breeding, as new knowledge about genomic structure and function sharply improve understanding of where to seek desirable food traits and how to incorporate them into commercial plants. The more controversial side of this revolution, inserting genes from different species into food crops as a way to incorporate attributes not feasible with traditional breeding, is the focus of this paper, but the “genetic revolution” will continue no matter what the result of the biotechnology debate.<sup>2</sup>

The challenge to “business as usual” for agricultural technology is first described, followed by a brief discussion of the first Green Revolution and its problems. Biotechnology can address many of these problems as well as push the yield frontier to new levels. This potential, and the problems standing in its way, are explained, with a concluding plea that the nutrition community become more actively engaged in explaining both potential and problems to the public.

<sup>1</sup> This is a written version of a speech presented as the “Invited Presidential Lecture” to the American Society for Nutritional Sciences (ASNS) at the annual meeting in San Diego, CA on April 14, 2003. I would like to thank President Jean-Pierre Habicht for inviting me and Dr. Maureen Mackey of Monsanto for supporting the event. At the time of the address, the author was Professor of Development Studies in the Graduate School of International Relations and Pacific Studies at the University of California, San Diego. E-mail: Peter\_Timmer@dai.com.

<sup>2</sup> Two especially useful books provide extensive background to the debate reviewed here: Richard Manning, *Food's Frontier: The Next Green Revolution*, University of California Press, 2000; and Per Pinstrup-Anderson and Ebbe Schioler, *Seeds of Contention: World Hunger and the Global Controversy over GM Crops*, Johns Hopkins University Press, 2001.

### *I. The Challenge*

The Millennium Development Goals (MDG)<sup>3</sup> agreed to by all Heads of State at the Millennium Summit Conference in 2000 seek to reduce levels of hunger, malnutrition and poverty by half by the year 2015, from their 1990 levels. Everyone agrees that these are very ambitious goals; reaching them will require sharp improvements in the rate of progress seen over the past half-century. Critical will be increasing the rate of economic growth in the poorest countries. In this task, agriculture plays at least three roles. Growth in agricultural productivity can stimulate faster economic growth, it tends to make this growth more “pro-poor” and it can provide the food supplies needed to reduce hunger.

Biotechnology, through genetically modified (GM) food, can help agriculture play these roles. But the train of logic is long and filled with caveats: biotechnology is *not* a magic bullet for ending hunger and malnutrition. Especially in a world in which markets are awash in food commodities, and rich countries spend roughly \$1 billion per day in subsidies to keep their farmers in business, the problems faced by farmers and consumers in poor countries are not going to be solved by technology alone.

How can biotechnology help? To answer this simple question, we need to understand the problems we are trying to solve. For this, a bit of history is in order, especially a review of the successes and failures of the first green revolution. If the *promise* of biotechnology is, in Gordon Conway's title, a “dou-

<sup>3</sup> Abbreviations used: GM, genetically modified; MDG, Millennium Development Goals; NGO, nongovernment organization; WTO, World Trade Organization.

bly green revolution," we need to understand the origins and effect of the "single" green revolution that started in the mid-1960s and which is still having a huge, positive influence on the welfare of billions of people, especially in developing countries.

## II. The Multiple Impact of the First Green Revolution

The first green revolution was accomplished through traditional breeding techniques, but with radical objectives to redesign the basic architecture of rice and wheat plants. The result was to raise the productivity of these two crucial grain crops significantly, especially in irrigated conditions. Because of the widespread effect of this green revolution in Asia, it lowered the real costs of staple food grains and made them much more affordable to the poor. The result, then, was to increase their food intake directly and improve their nutritional status and work capacity. It is useful to think of this as the first "Strong Link" in the array of connections between agricultural technology and reduced malnutrition.

Because food grains are the "wage good" in poor societies, lower food costs meant that employers could offer lower money wages at the same time that workers' living standards could increase. Thus, hiring more labor was productive (and profitable), and the additional hiring contributed directly to greater employment and reduced poverty. This is the second "Strong Link" in the array of connections (although possibly one only an economist could love).

Finally, the higher productivity from the green revolution technology contributed to growth in rural economies beyond the direct production effect and stimulated overall economic growth. This is the third "Strong Link" between agricultural technology and reduced malnutrition.<sup>4</sup>

In combination, these three links led to "pro-poor" economic growth, reduced poverty and sharply improved nutritional status in those societies that were able to capitalize on the potential of the first green revolution (mainly in Asia). The success of this growth experience has generated great interest in Washington in the nature of policies that stimulated such pro-poor growth, especially at USAID and the World Bank.<sup>5</sup>

## III. Problems with the First Green Revolution

Despite the production successes, the first green revolution faced or created a number of problems. The high yield varieties were very input intensive, especially in the use of pesticides and fertilizers, and they worked best on good soils with a high degree of water control (both irrigation and drainage). This input intensity raised many questions about the "sustainability" of high yield agriculture.

Second, the green revolution was mostly about rice and wheat. There were few gains for root-crops (cassava, potatoes, yams, sweet potatoes), traditional legumes such as lentils and

cowpeas, fruits and vegetables, even other cereal grain staples suitable for the semiarid tropics, such as millets and sorghum. Thus most of Africa and a good deal of the Indian subcontinent, where the biggest problems and challenges of hunger and poverty exist, were left out of the first green revolution.

Third, productivity gains using traditional breeding techniques have apparently been exhausted for rice and wheat. "Best practice" yields at research and experiment stations have been flat for over a decade. There is even some evidence of "frontier yields" declining, which may be a problem of soil quality.<sup>6</sup> Most of what we know about plants is how they function above the ground.

Hence, growth in cereal yields at the farm level in developing countries has slowed down significantly, from 2.9%/y from 1967 to 1982 to only 1.9%/y from 1982 to 1997. The International Food Policy Research Institute projects that these yields will grow at only 1.2%/y from 1997 to 2020.

Most fundamentally, because of the strong links between agricultural growth and performance in the rest of the economy, overall economic growth has slowed down as well. Indeed, a recent paper by Gaiha and Imai calculated the rate of growth in both agriculture and the overall economy required to meet the MDG.<sup>7</sup> To cut the "head-count index of poverty" in half, economic growth must reach 3.6–4.4%/y, and, as both a component and stimulant, agricultural growth must reach 4.0–4.5%/y. But the actual growth rates from 1985 to 2000 for these two variables were only 0.6 and 0.3%/y, respectively. In summary, this brief review of recent agricultural history and poverty alleviation argues that we must find a way to get *agriculture moving*.<sup>8</sup>

## IV. The Role for Biotechnology in the Food Systems of Developing Countries

There are five basic categories to be considered, ranging from general contributions to economic growth to very specific contributions that reduce malnutrition.

**A.** General yield advances, especially for key food crops, can stimulate agriculture-led growth and lower food prices. The economic mechanisms work through employment generation and food security for the poor. Biotechnology can improve yields of basic crops through insect protection, drought resistance and modifications to basic crop biology that could not be achieved through traditional breeding techniques.

**B.** Productivity gains for agricultural systems in degraded and hostile environments can be achieved through biotechnology because genetic potential already exists in some plants that thrive in these environments. Problems include salinity, aluminum toxicity and chronic drought. Many of the world's poorest farmers live in these difficult agricultural environments and improved productivity could have a direct effect on poverty in such settings.

**C.** Productivity gains for nongrain crops and livestock are possible from biotechnology, and these products have better demand opportunities as incomes increase and a middle class

<sup>4</sup> These links are not always easy to see because of the *structural transformation* of economies over the course of economic development. During this transformation, agriculture is a "declining sector" in relative economic importance, as industrial and service sectors grow faster. Still, the growth of agriculture is crucial to development of poor countries, especially to including the poor. This paradox has often been hard to understand on the part of both policymakers in poor countries and managers of donor agencies such as USAID and the World Bank. One of my major academic and advisory roles has been explaining this paradox. For an overview, see my chapter on "Agriculture and Economic Development," in: *The Handbook of Agricultural Economics*, Volume 2A, (Gardner, B. & Raussler, G., eds.), pp. 1487–1546. North-Holland, 2002 (available at [www.macrofoodpolicy.com](http://www.macrofoodpolicy.com)).

<sup>5</sup> See my paper on "Agriculture and Pro-Poor Growth" that was prepared in 2003 for USAID, also available at [www.macrofoodpolicy.com](http://www.macrofoodpolicy.com).

<sup>6</sup> See P. L. Pingali, M. Hossain, and R. V. Gerpacio, *Asian Rice Bowls: The Returning Crisis?* CAB International in collaboration with the International Rice Research Institute (IRRI), 1997.

<sup>7</sup> See Raghav Gaiha and K. Imai, "Millennium Development Goals, Agricultural Growth and Openness," May, 2003. Available at <http://www.econ.ox.ac.uk/Research/wp/pdf/paper161.pdf>

<sup>8</sup> The phrase refers to a famous book by Arthur Moshier, *Getting Agriculture Moving*, published in 1966.

<sup>9</sup> These categories are described in considerable detail in Maarten J. Chrispeels and David E. Sadava, *Plants, Genes, and Crop Biotechnology*, 2nd ed. Jones and Bartlett Publishers, 2003.

emerges. These gains will help stimulate agricultural diversification and thus permit farmers to get out of the "trap" of growing staple grain commodities with low income potential. China, in its commitments upon joining the World Trade Organization (WTO), is betting heavily on this strategy to solve its problem of rural poverty.

**D.** Genetically modified crops offer the possibility of reduced input use, especially of pesticides, which have had very serious health consequences for farm workers in countries with inadequate safety regulations on the use of hazardous chemicals. The potential for biotechnology to contribute to sustainable agricultural systems, through much more efficient utilization of water, nutrients and agricultural chemicals, may be its most important promise in the long run.

**E.** Biofortification of key foodstuffs with better availability of micronutrients such as iron and vitamin A is possible through biotechnology. Even this is a controversial area, as the heated debate over "golden rice" demonstrates. But the debate should not be about "all or nothing" effects. My colleague at the Fletcher School at Tufts University, Steve Block, has shown in joint research with Helen Keller International that even modest additions of vitamin A to the diets of poor children in Central Java can have noticeable health consequences because so many of them have serum retinol levels that are just below acceptable levels for normal growth and health. Modest improvements, if sustained by the food system itself, can have lasting welfare consequences.<sup>10</sup>

## V. What Stands in the Way of This Potential?

There are three categories of issues that are slowing the application of biotechnology to agricultural productivity in developing countries: scientific, economic and political.

The scientific issues are very complicated because there are so many avenues by which modern genetic technology can be used to improve the productivity of agricultural systems, many of which do not involve splicing genes into staple foods. An interested layman has to be impressed with the revolutionary speed of research advances. It seems as if almost anything is possible; thus, the key question is "what do we want?" The answers will come from the type of workshop held August 4–5, 2003, in Bogor, Indonesia, to assess the role of agricultural biotechnology for the country's future research efforts. This workshop gathered a spectrum of agricultural scientists, policy makers and nongovernment organizations (NGOs) to set priorities for commodity-based research.<sup>11</sup> Because of their importance to the Indonesian food system, rice, maize and sweet potatoes came at the top of the list.

The economic issues revolve around the key question "what will be profitable?" The answers will depend on the following: 1) consumer acceptance of GM products, including but not limited to foods (for example, there has been less consumer resistance to GM cotton than to foods, and economic production of biofuels is likely to meet little resistance as well); 2) regulatory costs of developing and utilizing GM technology; 3) supply and demand conditions in world commodity markets, which will themselves be influenced by developments in the GM field; and 4) the potential to develop "niche markets" for commodities that some farmers will be able to exploit (e.g.,

Peruvian asparagus grown in the North American winter season from tissue cultures started in Boston). Ultimately, agricultural biotechnology will succeed only if it is profitable for seed companies to produce it and farmers to use it.<sup>12</sup>

The political issues, without question, are the most difficult, and the mechanisms for resolving them remain highly imperfect. From the perspective of developing countries, there are five areas of concern and policy action, all with acute political dimensions:<sup>13</sup>

**1. Intellectual Property Rights.** A key issue concerns the rights of farmers to retain and use patented seeds without paying royalties. The desire of patent holders to find a natural mechanism to make regular payments "necessary" led to development of the "terminator gene" which, understandably, caused great controversy and was never put into commercial use. Intellectual property rights were not a problem with hybrid seed technology because second generation seeds do not breed true.

There are two dimensions to this problem. The first is the ease with which individual farmers can keep productive seed for planting in following years without paying again, even if their payment for the seed in year 1 includes a contract to pay in future years. Enforcing contracts may not be difficult in the United States or Europe, but it is likely to be an enormous challenge in the developing world. Second, there is a concern among NGOs and policy makers that GM seeds could force traditional seeds, and domestic seed companies, out of the system, leaving a country's food supply in the hands of a few large, often foreign, companies.

In response to these concerns, attention has focused on the patent process and who owns the basic genetic "rights" to staple foods. In a recent "Policy Forum" in *Science*, senior leaders of U.S. public universities proposed a new model for collaboration to keep patented discoveries in agricultural biotechnology as "public goods."<sup>14</sup> This initiative does not, however, address the issue of methodological patents that are already in the hands of private companies. These patents require royalty payments during the research phase and considerable transaction costs in negotiating "freedom to operate" arrangements before commercialization of GM seeds begins.

**2. Biosafety.** Biosafety concerns are primarily about release of exotic genetic material into "native" ecosystems, with unknown effect on long-run sustainability and biodiversity. A British government assessment in 2003 of the safety of GM crops was generally positive, but "concluded that the most important issue is the potentially detrimental effect on farmland biodiversity, soil ecology, allergenicity, and gene flow to non-GM plants."<sup>15</sup> Further farm trials in the United Kingdom are underway to resolve this uncertainty.

**3. Trade in GM Products.** The concern about trade in GM products arises because of the threat of boycotts of agricultural exports from countries using GM technology, even when the exported product is not a GM crop. Although enforcing such threats would presumably be illegal under the

<sup>10</sup> See Steven Block, et al., "Did Indonesia's Crises of 1997/98 Affect Child Nutrition? A Cohort Decomposition Analysis of National Nutrition Surveillance Data." Working Paper No. 90, Center for International Development, Harvard University, 2002.

<sup>11</sup> Organized by the Cornell University Agricultural Biotechnology Support Project II (ABSP-II) Team in collaboration with the Indonesian Agency for Agricultural Research and Development (IAARD) and financed by USAID.

<sup>12</sup> The reality of this was stressed in a review of Monsanto's experience with agricultural biotechnology. See David Barboza, "Monsanto Finds Itself Struggling for Profit Even in Markets it Dominates." *New York Times*, Saturday, May 31, 2003, pages D1 and D14.

<sup>13</sup> For more details, see Rob Paarlberg, *Governing the GM Crop Revolution: Policy Choices for Developing Countries*, IFPRI Discussion Paper 33, December, 2000.

<sup>14</sup> See Atkinson et al., "Public Sector Collaboration for Agricultural IP Management," in "Policy Forum: Intellectual Property Rights," *Science*, July 11, 2003 (Vol. 301), pages 174–5.

<sup>15</sup> Reported by John Pickrell in *Science*, July 25, 2003 (Vol. 301), pages 447–8. The report itself is available at [www.gmsciencedebate.org.uk/report/default.htm](http://www.gmsciencedebate.org.uk/report/default.htm)

WTO, the threats alone cause most developing countries to be very careful about approving the import or growing of GM commodities. This concern is focused especially on threats from Europe, and the UK study noted above was a first step in addressing the Europe-wide moratorium on approving new GM products that has been in existence since 1998. At the August meeting in Bogor to assess crop biotechnology priorities in Indonesia, the likelihood that any of the GM commodities Indonesia might produce would be exported raised a cautionary flag, whether Europe was the destination or not. Once food products enter international trade, it is difficult to be certain what the final consumer market will be, especially for basic oils, starches and spices used widely in food processing. Indonesia, for example, is a major producer and exporter of many of these basic commodities.

**4. Food Safety and Consumer Choice.** Much of the political opposition to GM foods in Europe arises from widespread consumer doubts over their safety because of the perception that GM foods are “unnatural” or unhealthy. The UK report found no evidence to support these doubts, but there has also been relatively little benefit to consumers from existing GM foods on grocery shelves. This could change if preserving the identity of non-GM foods proves to be extremely costly, so that substantial price discounts can be offered on foods containing GM ingredients. As an example, evidence of consumer willingness to pay for organic foods suggests that a 30% differential becomes too much for all but the most dedicated. Organic foods have spread rapidly when cost differentials with traditionally grown foods have been modest, but that is possible only as long as the organic sector remains a niche player in overall supplies. Foods produced using biotechnology offer continued downward trends in costs and prices, which are likely to be increasingly attractive to consumers, if they have the choice.

**5. Public Research Investments.** Even poor countries need to invest public resources in the scientific capacity to evaluate the appropriate fit of GM crops to local environments and consumer attitudes, as the Indonesian Biotechnology Assessment Workshop indicated. What domestic research capacity is required in biotechnology, even if only for regulatory and safety purposes? Because the current scientific approach to these issues is conducted on a crop-by-crop, even trait-by-trait basis, countries intending to plant GM crops in their local fields will require substantial capacity to review the issues on a timely basis. Even if consumption of imported GM foods is all that is contemplated, the regulatory and food safety authorities will have to be cognizant of approaches in other countries, and competent to judge the adequacy of approvals made by other nations’ regulatory authorities. All of this argues that substantial local scientific expertise will be required in biotechnology.

After discussing these five policy issues, Paarlberg studied four cases: Brazil, China, India and Kenya. He discovered that only China seemed to be pursuing an “independent” approach to GM technology with respect to the country’s own needs. The others were heavily influenced in their approaches by external pressures, especially from European countries and vocal NGOs, mostly with links to and funding from parent NGOs in developed countries. Even China has put a moratorium on the commercial release of further GM agricultural commodities in 2003 as concerns mounted over their effect on trade access to European markets.

The rather sad case of Bt-Maize from the United States, to be used as food aid in southern Africa to cope with the severe drought in 2002, but rejected by several countries as “unsafe,” illustrates just how radically split the political communities are over GM food. The “Precautionary Principle” is often invoked

in these arguments, especially in defense of the European moratorium and European efforts to impose it on developing countries that trade with Europe. But this principle is more a mechanism for defending an entirely different kind of agricultural policy in Europe than a scientifically valid way of evaluating a new technology for costs and benefits.<sup>16</sup> In its most extreme form, the precautionary principle argues that even large benefits cannot offset the possibility of costs to human health or the environment, no matter how small that possibility is deemed to be by the scientific community. Invoking the precautionary principle as a decision tool for public policy inevitably leads to stalemate in technology adoption. When the technology lowers the costs of food production or improves its nutritional quality, it is the poor who suffer.

## VI. What Next?

The only way out of this political stalemate seems to be to create partnerships that cut across interests in a mutually productive way. Three are offered for consideration here:

**A.** Partnerships between universities and the private sector, especially in basic genetic research. A good example in San Diego, where this speech was given, is the Center for Molecular Agriculture at the University of California, San Diego, directed by Professor Maarten Chrispeels.

**B.** Partnerships between agricultural companies and development foundations. The best example is the recently announced African Agricultural Technology Foundation, set up by the Rockefeller Foundation in Nairobi, Kenya, with financial support from USAID and DFID (the British aid agency). Four big companies have joined: Monsanto (St. Louis, MO), DuPont (Wilmington, DE), Dow AgroSciences (Indianapolis, IN) and Syngenta (Basel, Switzerland). These companies have agreed to share their biotechnology freely with African scientists. They will donate patent rights, seed varieties, laboratory know-how and other aid.<sup>17</sup>

What is the benefit for these companies (and their shareholders)? For a start, they are receiving some good press and lots of good will. No doubt, these corporate partners are hoping the action will also help resolve some other issues on the policy table. From the Foundation’s perspective, the hope is that biotechnology will help Africa develop and start making progress against its rising levels of poverty. For all the partners, the hope has to be that Africa will become a market for other products. For the time being, hopes are high (the most important word in each sentence is “hope”), but progress is likely to be very slow in view of European opposition.

**C.** A third partnership must be created between the nutrition community and the biotechnology opinion makers, i.e., NGOs and policy analysts. The nutrition community must become engaged in these debates. It has the scientific expertise and public credibility to be an effective voice for reason and to counter the misinformation and fear that are so widely disseminated by many activist groups. It is time to use this expertise and credibility on behalf of improved nutrition for the poor.

<sup>16</sup> The Common Agricultural Policy (CAP) of the European Union is designed to minimize structural change in agriculture and thus preserve “family farms.” It does this through a variety of protectionist mechanisms, including export subsidies, guaranteed domestic prices and payments for environmental “services” provided by agriculture. From this perspective, banning GM foods is simply one more mechanism for avoiding foreign competition facing European farmers. For this reason, the United States is challenging the European approach to GM foods at the WTO.

<sup>17</sup> See Justin Gillis, “To Feed Hungry Africans, Firms Plant Seeds of Science,” *Washington Post*, Tuesday, March 11, 2002, page A01.