Agricultural Biotechnology Overview

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Every year, millions of people worldwide die from starvation and nutritional deficiencies. Although these challenges remain significant, we are making some progress. During the past 50 years, agricultural technologies have increased food availability and caloric intake on a per capita basis in nearly every nation of the world. Much is left to be done, however. Some 740 million people go to bed daily on empty stomachs, and nearly 40,000 people—half of them children—die every day from hunger or malnutrition-related causes.[1] Two significant and interrelated challenges are (a) to increase farm productivity in less developed countries, where food is most needed, so that today's subsistence farmers can use agriculture for their own economic development and (2) to increase per-acre yields so that the amount of food harvested can rise without having to bring undeveloped land into agricultural production.

Technology has transformed agriculture, medicine, and other industries; the record of agricultural progress during the past century speaks for itself. Those countries that developed and embraced improved farming technologies have brought unprecedented prosperity to their people, made food much more affordable and abundant, helped to stabilize farm yields, and reduced the destruction of wild lands.[2] But con-

1. Per Pinstrup-Andersen and Rajul Pandya-Lorch, eds., *The Unfinished Agenda: Perspectives on Overcoming Hunger, Poverty, and Environmental Degradation* (Washington, DC: International Food Policy Research Institute, 2001).

2. Norman Borlaug, "Ending World Hunger: The Promise of Biotechnology and the Threat of Antiscience Zealotry," *Plant Physiology* 124 (October 2000): 487–90.

tinued technological development—including, in many cases, the use of agricultural biotechnology—is crucial if we want to further reduce starvation and malnutrition and meet the needs of growing populations while also lightening humankind's environmental impact.

Unfortunately, misperceptions about biotechnology—known variously as bioengineering, gene splicing, genetic modification, and recombinant DNA (deoxyribonucleic acid) technology—have led to activist calls for heavy restrictions or outright bans. In the United States, the introduction of new bioengineered crop varieties has slowed in the past few years because of duplicative and costly regulations and because of farmers' concerns that they would be unable to sell harvested bioengineered crops in major export markets. In Europe and parts of Asia, antibiotechnology movements are strong and have succeeded in generating stringent national regulations and international trade restrictions. While industrial nations are already using forms of innovative agricultural technologies and may be able to absorb the costs of such restrictive policies, people in less developed countries will pay a high price for imprudent regulation because many continue to suffer from food shortages and malnutrition.

What Is Biotechnology?

The term *biotechnology* has been used for nearly 100 years to describe any application of living organisms to create consumer or industrial products.[3] That definition encompasses old and new processes such as the use of *Penicillium chrysogenum* mold to produce penicillin or the addition of natural enzymes to laundry detergents. Biotechnology also could describe many traditional types of plant breeding. Recently, however, the term has come to represent only the most advanced recombinant DNA (rDNA) techniques. In this policy brief, *biotechnology* has the latter, more specific meaning.

Agricultural biotechnology uses advances in genetics and cell biology to move useful traits from one organism to another. Scientists scan the genome of various organisms—most often other plants or microorganisms—to identify individual genes that produce useful traits. The genes are then cut out of the host organism's DNA and moved to the genome of a crop plant, thereby transferring the useful trait. A gene from the harmless soil bacterium *Bacillus thuringiensis* allows plants to better protect themselves from insect pests.[4] Other genes help farmers more effectively combat weeds, plant diseases, and environmental stresses such as poor soils and temporary drought.[5] Biotechnology also has been used to improve the nutritional quality of staple foods like corn and rice by adding healthful vitamins and minerals.[6] Unfortunately, many of these plant varieties remain uncommercialized due to excessive regulatory burdens and politicized approval processes.

The scientific literature is filled with hundreds of peer-reviewed studies describing the

3. Henry I. Miller and Gregory Conko, *The Frankenfood Myth: How Protest and Politics Threaten the Biotech Revolution* (Westport, CT: Praeger, 2004).

4. Janet Carpenter, Allan Felsot, Timothy Goode, Michael Hammig, David Onstad, and Sujatha Sankula, *Comparative Environmental Impacts of Biotechnology-Derived and Traditional Soybean, Corn, and Cotton Crops* (Ames, IA: Council on Agricultural Science and Technology, 2002).

5. Ibid.

6. Dean Della Penna, "Nutritional Genomics: Manipulating Plant Micronutrients to Improve Human Health," *Science* 285, no. 5426 (1999): 375–79.

safety of bioengineered crops and foods. And a review of 81 separate research projects, conducted over 15 years and funded by the European Union found that bioengineered crops and foods are as safe for the environment and for human consumption as conventional ones—and in some cases even safer, because the genetic changes in the plants are much more precise.[7] This confidence has been validated by the excellent safety record of biotech crops and the food derived from them since their commercial introduction more than a decade ago.[8]

In 2005, 8.5 million farmers in 21 countries planted more than 220 million acres with bioengineered crops—primarily soybeans, cotton, corn, and canola.[9] It's easy to see why. In 2001 alone, biotechnology-derived plants increased U.S. food production by approximately 4 billion pounds, saved $1.2 billion in production costs, and decreased pesticide use by about 46 million pounds.[10] They have improved air, soil, and water quality as a consequence of reduced tillage, less chemical spraying, and fuel savings, and they have enhanced biodiversity because of lower insecticide use.[11] Not surprisingly, farmers have a very favorable view of biotech seeds. By 2006, 61 percent of all corn, 89 percent of all soybeans, and 83 percent of all upland cotton grown in the United States were bioengineered varieties.[12]

Unremarkably, most commercially available biotech plants were designed for farmers in the industrial world. However, the increasing adoption of bioengineered varieties by farmers in less developed countries over the past few years has shown that these farmers can benefit at least as much as, if not more than, their counterparts in industrial countries.[13]

The productivity of farmers everywhere is limited by crop pests and diseases—and they are often far worse in tropical and subtropical regions than in temperate zones. About 20 percent of plant productivity in the industrial world—but up to 40 percent in Africa and Asia—is lost to insect pests and pathogens, despite ongoing use of copious amounts of pesticides.[14] The European corn borer destroys approximately 7 percent, or 40 million tons, of the world's corn crop each year—a sum equivalent to the annual food supply in calories for 60 million people.[15] It should come as no surprise that, when per-

7. Charles Kessler and Ioannis Economidis, eds., *EC-Sponsored Research on Safety of Genetically Modified Organisms: A Review of Results* (Brussels: Office for Official Publications of the European Communities, 2001).

8. National Research Council, *Safety of Genetically Engineered Foods: Approaches to Assessing Unintended Health Effects* (Washington, DC: National Academies Press, 2004).

9. Clive James, "Global Status of Commercialized Biotech/GM Crops: 2005," ISAAA Brief 34-2005, International Service for the Acquisition of Agribiotech Applications, Ithaca, NY, 2005.

10. Leonard Giannessi, *Plant Biotechnology: Current and Potential Impact for Improving Pest Management in U.S. Agriculture: An Analysis of 40 Case Studies* (Washington, DC: National Center for Food and Agricultural Policy, 2002).

11. Carpenter et al., *Comparative Environmental Impacts*.

12. National Agricultural Statistics Service, *Acreage* (Washington, DC: U.S. Department of Agriculture, June 30, 2006).

13. James, "Global Status of Commercialized Biotech/GM Crops."

14. Chris Sommerville and John Briscoe, "Genetic Engineering and Water," *Science*, 292, no. 5525 (2001): 2217.

15. C. S. Prakash and Gregory Conko, "Agricultural Biotechnology Caught in a War of Giants," in *Let Them Eat Precaution: How Politics Is Undermining the Genetic Revolution in Agriculture*, ed. Jon Entine (Washington, DC: American Enterprise Institute, 2006), 35–55.

mitted to grow bioengineered varieties, poor farmers in less developed nations have eagerly snapped them up. Although industrial countries still grow the most, nearly 40 percent of biotech crop acreage is in less developed countries. And 90 percent of the farmers growing bioengineered varieties are resource-poor farmers in countries such as China, India, the Philippines, and South Africa.[16]

Is Crop Biotechnology Safe?

Many biotechnology skeptics contend that such engineering is unsafe because it is "unnatural," or because the technology is so new that plant breeders cannot anticipate all the potentially negative effects. As a result, they call for special regulations on biotech food, as well as on the gene-splicing process itself. Ironically, biotechnology is actually an improved method for plant breeding that gives researchers greater control and better understanding of the final plant product.

For thousands of years farmers changed the genetic characteristics of plants simply by selecting seeds from the best plants for propagation the following year. Hybridization—the mating of different plants of the same species—assimilates desirable traits from several varieties into elite specimens. Although most people believe that conventional plant breeding amounts to nothing more than simple selection and hybridization, nothing could be further from the truth.[17]

When desired characteristics are unavailable in cultivated plants, genes can be liberally borrowed from wild relatives and introduced into crop varieties, often of different but related species. For example, wheat, rye, and barley are regularly mated with wild grass species to introduce new traits.[18] Such wide crosses between crop and wild varieties typically do not produce offspring, however, because the embryos die before they mature into seeds. Therefore, the embryos must be "rescued" and cultured in a Petri dish. Even then, the rescued embryos typically produce sterile seed, which can be made fertile again only by using chemicals that cause the plants to mutate and produce a duplicate set of chromosomes. Successive generations then have to be carefully screened to eliminate unwanted traits accidentally transferred from the wild plants, such as toxins common in most wild species. Triticale, an artificial hybrid of wheat and rye, is one example of a wide-cross hybrid made possible solely by embryo rescue and chromosome-doubling techniques. Triticale is now grown on more than 3 million acres worldwide, and dozens of other products of wide-cross hybridization are common.

When a desired trait cannot be found within the gene pool of related plants, breeders can create new variants by intentionally mutating plants with radiation or chemicals or by simply culturing clumps of cells in a Petri dish and leaving them to mutate spontaneously during cell division. Mutation breeding has been common since the 1950s, and more than 2,250 known mutant varieties have been bred in at least 50 countries, including Australia, France, Germany, Japan, the United Kingdom, and the

16. James, "Global Status of Commercialized Biotech/GM Crops."

17. C. S. Prakash, "The Genetically Modified Crop Debate in the Context of Agricultural Evolution," *Plant Physiology* 126 (May 2001): 8–15.

18. Robert M. Goodman, Holly Hauptli, Anne Crossway, and Vic C. Knauf, "Gene Transfer in Crop Improvement," *Science* 236, no. 4797 (1987): 48–54.

United States.[19] New mutant crop varieties are commercialized frequently, and mutant wheat, rice, and canola varieties have been introduced in the United States, Canada, and Australia, in recent years.[20]

More important, wide-cross hybridization and mutation breeding are among the methods considered to be conventional breeding, so they are not opposed by antibiotechnology activists, nor are they subject to regulation in most of the world. Still, conventional breeding involves gross manipulation of plant genetic material, which is why scientists view modern biotechnology, using rDNA methods, as an extension of conventional techniques, not a totally new approach.[21] The primary difference is that the development of modern bioengineered crops involves a precise transfer of one or two known genes into plant DNA—a surgical alteration of a tiny part of the crop's genome compared with the traditional sledgehammer approaches whose genetic changes are mostly unknown and unpredictable.

The National Research Council summarized this issue neatly in a 1989 report:

> With classical techniques of gene transfer, a variable number of genes can be transferred, the number depending on the mechanism of transfer; but predicting the precise number or the traits that have been transferred is difficult, and we cannot always predict the [behavior] that will result. With organisms modified by molecular methods [i.e., biotechnology], we are in a better, if not perfect, position to predict [their behavior].[22]

Updated 2008.

19. M. Maluszynski, K. Nichterlein, L. Van Santen, and B. S. Ahloowalia, *Officially Released Mutant Varieties: The FAO/IAEA Database* (Vienna, Austria: Joint FAO-IAEA Division, International Atomic Energy Agency, December 2000).

20. Clearfield Production System (BASF Corporation, Research Triangle Park, NC, 2005). Available at, http://www.agro.basf.com/p02/AP-Internet/en_GB/function/conversions:/publish/upload/CLEARFIELD-Brochure.pdf.

21. National Research Council, *Safety of Genetically Engineered Foods*.

22. National Research Council, *Field Testing Genetically Modified Organisms: Framework for Decisions* (Washington, DC: National Academies Press, 1989), 13–14.