# Agricultural Biotechnology and the Environment

## Science, Policy, and Social Issues

Sheldon Krimsky
and
Roger Wrubel

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Agricultural Biotechnology and the Environment: Science, Policy, and Social Issues *Sheldon Krimsky and Roger P. Wrubel*

Agricultural Biotechnology and the Environment

Dedicated to Robert S. Cohen

—S.K.

For Roberta and Ari

—R.P.W.

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Agricultural Biotechnology and the Environment

# Contents

# Introduction

Two decades after new biological methods for recombining hereditary material in living organisms were introduced into science and industry, it now seems clear that biotechnology has a secure place among major technological breakthroughs of the twentieth century. Although the industry is still young, there is sufficient evidence for its future growth in pharmaceuticals, diagnostics, and food production.

When historians consider the last quarter of this century, they will note that the discovery and commercial applications of biotechnology did not come without some social resistance and public skepticism. Initially, scientists called attention to potential hazards when gene splicing was first reported in the literature (Krimsky 1982). As the concerns over laboratory hazards waned, public attention was directed toward the technology, the manufacturing and agricultural processes, and the consumer products that resulted from biotechnology. The din of controversy spread over a broad spectrum of issues, including patenting of life, human genetic engineering, genetic screening and identification, the release of genetically modified organisms into the environment, and the production of genetically engineered food, plants, and animals.

As these controversies rise and fall, inevitably the question will be, What was all the fuss about biotechnology? Is applied genetics so different from other technologies? Have industrial nations created higher standards for the adoption of genetic technologies beyond those required for past technological innovations? Or perhaps we are naive in thinking that contemporary societies have selected biotechnology for special treatment. Nuclear and chemical technologies have certainly been met with a formidable degree of public opposition. Even computer technologies have their detractors. There is a notable difference, however. With biotechnology, the public's scrutiny has come at the early stages of innovation, before the technologies are on-line and before products are marketed. One cannot say the same about the introduction of nuclear and chemical technologies.

Nevertheless, countless thousands of innovations in products and technological processes are introduced into manufacturing plants and the consumer market annually, with citizens having little or no awareness of the changes. Perhaps we are more likely to take note of new technologies when we use them directly and when they offer a new function or a replacement for an old one. Material substitutions are noticeable to the consumer when the product differences are pronounced, such as a change from metal to plastic fabrication. For each innovation that is discernible to the consumer, scores of others are hidden from public view. How many people would be able to detect a change in the composition of a plastic container, or in the chemical sprays used on new clothing to maintain freshness, or in the type of pesticides used on vegetable crops? The entry of homogenized milk into consumer markets was immediately obvious, but the introduction of a microbially derived growth hormone (called bovine somatotropin) on cows will not be discernible by taste or observation.

A colleague at the Tufts University Medical School tells the story of how the controls of her experiment designed to detect the presence of chemicals that mimic the function of human estrogens were contaminated. She scrutinized her laboratory and every piece of equipment. She telephoned manufacturers to determine whether changes had been made in the formulation of plastic products. One manufacturer of tubing confirmed her suspicion. The polymers in the plastic tube had been modified, she was told, but the new formula was a trade secret. The medical school researcher had the plastic analyzed and discovered in the new composition another industrial chemical with estrogenic properties.

Notwithstanding the fact that changes in manufacturing processes and products take place continuously, technological innovations are rarely debated in the public arena or the media. Industrial societies have come to place great trust in technological change. The impulse for and nourishment of change in manufacture is part of the *Weltgeist* of the modern industrial state. As a consequence, the public has very little control over industrial innovations, which are presumed to be in the public interest by virtue of their success in the marketplace unless proven otherwise. Every state has some minimal ground rules for the adoption of a new product or technology, for example, that they not introduce unacceptable risks to human health and safety or to the environment. As long as the threshold conditions are satisfied, the norms of the market economy, for example, microeconomic efficiency and profit maximization, take over.

Over the past century some of the most notable achievements in technology have been in agriculture. Once a highly decentralized and labor-intensive system of production, modern farming is evidence that industrial mass production was applicable to the growth of crops and the production of livestock. Just as the size of factories increased to enable manufacturers and investors to capitalize on economies of scale, the concept of efficiency applied to farming sought the optimum use of land, air, water, soil, and germ plasm, eventually resulting in integral roles for electrification, mechanization, chemicals, and management science in food production. Innovations in agriculture also shape the system of social relations and the institutions associated with food production. For example, it has been noted that the cotton gin made it possible for the South's plantation owners to preserve slavery as an economically viable system.

American farmers have achieved among the highest levels of land and labor productivity in the world. A mere 1.5 percent of the U.S. population provides enough food for domestic and export markets. By 1990, 320,000 large farms produced 77 percent of the total national agricultural product (Cochrane 1993, 460). Biotechnology offers farmers and seed manufacturers the tools for securing additional improvements in agricultural yield. It began its ascendancy in investment circles as a blossoming but unproven high-technology sector about the same time the U.S. manufacturing industry began to decline internationally. As financial markets were bullish over biotechnology, hundreds of new firms were created with research ideas germinated in academic laboratories. According to the Office of Technology Assessment, "The boom in biotechnology company formation occurred from 1980 to 1984, with nearly 70 new firms begun in 1981 alone" (OTA 1988, 9). U.S. funding agencies began a massive research initiative to investigate the role of biotechnology in medicine and agriculture. In 1990 the federal government expended more than \$3.4 billion in overall R&D in biotechnology-related projects. The bulk of those funds, \$2.9 billion, came from the National Institutes of Health compared to \$168 million and \$116 million from the National Science Foundation and the Department of Agriculture, respectively (OTA 1991, 21). Between 1991 and 1993 the public investment in about one thousand American biotechnology companies amounted to \$6 billion. Approximately fifty of these firms were involved in agricultural biotechnology, with investments exceeding $200 million annually (Caswell et al. 1994, 7). The innovative potential of gene engineering was often described as being without limits. At the same time, many R&D projects were not pursued beyond their early public relations announcements.

Some companies decried the lack of clear regulations; others struggled with negative public opinion of biotechnology. There were suggestions that regulatory obstacles had slowed the pace of innovation. The Congressional Office of Technology Assessment affirmed that "when regulation is untried in the marketplace, untested in the courts, or ambiguous in status and scope, the resulting set of uncertainties can become a dominant influence in selecting or rejecting an R&D objective and associated business strategy" (OTA 1988, 100).

For more than a decade, agricultural research has begun to respond to the promise of applied molecular genetics. New research centers blossomed at land grant colleges and other universities. Biotechnology industrial parks were sought as jump-starters for local economies. A number of states such as California promoted biotechnology investments in advertising campaigns directed at new companies. One city even used Housing and Urban Development Block Grant funds to provide loans to biotechnology firms that might locate there (H. Miller 1993, 5). Investing in America's future meant investing in biotechnology.

In 1991 the Office of Technology Assessment listed four areas where biotechnology would contribute to agriculture (99):

- gains in yield through new plants resistant to environmental stresses;
- lower costs in labor and agricultural inputs;
- higher-quality food and value added products; and
- environmentally benign methods of managing weeds and insect pests.

This book examines the directions of research and development for the first generation of agricultural products and generic product categories arising from the applications of new tools in genetic engineering. We are interested in why certain paths of innovation were preferred over others and which factors shaped the direction of new biotechnology products. What, for example, has been the impact of regulation or lack thereof in the investment strategy for agricultural biotechnology products? What has been the outgrowth of social and environmental concerns resulting from the choices of new technologies?

In the early 1980s when venture capital and Fortune 500 investments in biotechnology were being sought, many expectations were discussed for the fledgling industry. More than a decade later it is possible to compare these early expectations with the realities of current product development and research trajectories. For example, while biotechnology was being cast as environmentally friendly, the industry has not been embraced by environmental organizations. Quite the contrary, major environmental groups have spoken critically of new biotechnology products. In this volume we have sought to answer whether current trends in agricultural biotechnology are likely to promote safer insecticides, promote sustainable agriculture, create more biodiversity, or reduce dependency on fossil fuel and chemically intensive farming.

We also focus on the public reception to the first generation of biotechnology products. To what extent does the progress of innovation match the public's expectation? What are the sources of public apprehension? How deep are society's ideological divisions over biotechnology?

This book is organized around generic product types such as disease resistant crops and transgenic animals. Each chapter provides a systematic overview of scientific developments. Some chapters include interview data from leading-edge biotechnology companies on the state of the art in product development. The technical analysis of research and product development leads to consideration of other contextual issues, such as the anticipated economic benefits, environmental effects, public perceptions, and the social and ethical implications associated with the research agenda.

Chapter 1 explores the issue of change in agricultural biotechnology through a general discussion of technological innovation and diffusion in agriculture. The innovation pathways in biotechnology are fashioned by a superposition of government policies, technological maturation, technology transfer mechanisms, regulations and incentives, and social values. The significance of these factors is sorted out through specific cases.

Chapters 2–5 examine the science and social issues associated with transgenic crops; each chapter focuses on a generic class of products and research programs. Chapters 6–8 address transgenic microorganisms in three agricultural applications: insecticidal, nitrogen-fixing, and frost-inhibiting bacteria. Chapters 9 and 10 discuss transgenic animals, the former examining current science, ethics, and social considerations and the latter human health and