



# Introduction

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“Healthy discontent is the prelude to progress.”

— Mahatma Gandhi (1929)

The beneficial role of biotechnology in improving crop yields is well established. However, several recent studies have also revealed that there are significant risks associated with genetically modified (GM) crops — risks that may adversely affect our health and environment. Long-term studies are urgently needed to produce results which may be able to resolve these questions, yet such data have not been forthcoming. If this book raises too many questions, it is because they are timely. Biotechnology is at a critical juncture where several developing countries are poised to make large investments in GM crop research and expand their cultivation nationwide. The need for risk evaluation has never been greater than it is today. Underneath this critical approach is the basic optimism that biotechnology will be able to provide the means to feed the world’s hungry, provided that the potential risks are first evaluated and dealt with. It would be unwise to proceed with the planting of GM crops on a large scale until the risks to health and environment are fully evaluated.

As a geneticist and biotechnologist, I have been keenly interested in the rapid development of biotechnology since 1980, when Ananda Chakrabarty successfully patented a live human-made microorganism, which was approved by the U.S. Supreme Court in a 5–4 decision in the case of *Chakrabarty v. Diamond*. It involved a GM bacterium, *Pseudomonas aeruginosa*, which was designed to break down four of the main components of crude oil. This was an important step because it marked a new beginning for patenting man-made living organisms: it was based on the premise that the patent legislation, which was earlier enacted by the U.S. Congress, does not distinguish between living and nonliving matter. Until then, microorganisms were considered to be products of nature and thus not patentable.

The Chakrabarty patent provided the judicial framework for the U.S. Patent and Trademark Office to determine later that plants and animals are patentable subject matter under the U.S. code. It is a well-known fact that the Chakrabarty patent provided great economic stimulus to the patenting of microorganisms and cells, as well as a great incentive for the growth of the biotechnology industry.

## **Biotechnology and Biodiversity**

Since the exciting and hopeful prospect of abundance that was initially expected of biotechnology, we have come a long way. Biotechnology has indeed produced many benefits. Food production has increased manifold, although population growth has outstripped achievements in agriculture. It has become clear during the last several years that the “green revolution”, pioneered by Prof. M.S. Swaminathan, that was so successful in carrying India forward during the last 30 or 40 years is no longer adequate. This is due to several complex factors which have been discussed by others (e.g. Swaminathan 1999). What is needed is an “evergreen revolution”, or perhaps several such revolutions, occurring periodically to meet the demands of an ever-growing population. The area of agricultural land is shrinking rapidly, due to the explosive

growth of human and animal populations followed by habitat destruction.

### **Causes for Declining Agrobiodiversity**

The principal underlying causes for declining agrobiodiversity include the rapid expansion of industrial and Green Revolution agriculture, intensive livestock production, and industrial fisheries and aquaculture (some production systems using GM varieties and breeds) that cultivate relatively few crop varieties in monocultures, rear a limited number of domestic animal breeds, or fish for or cultivate few aquatic species. Variety replacement is the main cause of losses. The replacement of local varieties or landraces by “improved” and/or exotic varieties and species is reported to be the major cause of genetic erosion around the world.

Globalization of the food system and marketing, as well as the extension of industrial patenting and other intellectual property systems to living organisms, has led to the widespread cultivation and rearing of fewer varieties and breeds for a more uniform and less diverse, but more competitive, global market. The consequences are marginalization of small-scale, diverse food production systems that conserve farmers’ varieties of crops and breeds of domestic animals, which form the genetic pool for food and agriculture in the future; reduced integration of livestock in arable production, which reduces the diversity of uses for which livestock are needed; and reduced use of “nurture” fisheries techniques, which conserve and develop aquatic biodiversity.

Genetic erosion refers to the loss of genetic diversity, including the loss of individual genes and gene complexes (particular combinations of genes), such as those manifested in locally adapted landraces. The main cause of genetic erosion in crops, as reported by almost all countries, is the replacement of local varieties by “improved” or exotic varieties and species. As old varieties in farmers’ fields are replaced by newer ones, genetic erosion frequently occurs because the genes and gene complexes found in the diverse farmers’ varieties are not contained

in the modern varieties. In addition, the sheer number of varieties is often reduced when commercial varieties are introduced into traditional farming systems. There have been few systematic studies of the genetic erosion of crop genetic diversity that have provided quantifiable estimates of the actual rate of genotypic or allelic losses.

### **Benefits of Agricultural Biodiversity**

Prime Minister Manmohan Singh of India pointed out that in the past, the community food tradition assured that a wide range of food crops rich in protein, iron, micronutrients, and vitamins was available to the people; however, commercial agriculture has narrowed the range of food crops available.

Agricultural biodiversity can help in developing decentralized community food security systems that benefit local communities. They are also beneficial for long-term security through the establishment of gene banks, seed banks, and grain banks, which can be managed by local people. The diversity of crops could also reduce pesticide use. Furthermore, tropical fruits, sweet potato (with beta-carotene), and other vegetable crops can fight vitamin A deficiency in children.

Agricultural biodiversity provides the important raw material for improving the quality of crops, livestock, and fish. It can also create opportunities for entrepreneurship by generating employment and additional income from a whole range of value-added foods, medicines, nutraceuticals, biofuel, and other sources. On a global scale, nearly 2.5 billion people depend directly on wild and traditionally cultivated plant species to meet their daily needs.

### **Toxic Effects**

Unfortunately, there are other consequences of biotechnology that are clearly undesirable. The picture that has emerged from recent studies is unfavorable, even alarming, if the results are confirmed in long-term studies. While we are even more convinced today that

biotechnology will continue to be needed for feeding the world's billions in the future, there is evidence which indicates that a cautious approach is very much warranted. The method of achieving greater food production by utilizing GM crops, as we have done so far, appears to have some significant associated risks to our health and environment. A few examples will suffice.

An analysis of results obtained when rats were fed GM corn (MON 523 produced by Monsanto Corp.) was recently published by Prof. Gilles-Eric Seralini (2007) from the University of Caen, France. The study, completed at CRIIGEN (Caen, France), examined the raw data on MON 863 feeding experiments on rats, initially suppressed by Monsanto but later obtained by others in 2005 after a court action in Germany. Using more sophisticated analytical methods than those employed by Monsanto, the new study uncovered an increase of up to 40% in blood triglycerides in female rats, and a more-than-30% decrease in urine phosphorus and sodium in male rats, specifically linked to the GM diet. The reasons for these changes are unclear, but they may provide clues to the deaths of many animals which consumed *Bacillus thuringiensis* (Bt) feed in other animal experiments. However, these data should be confirmed further using large numbers of experimental animals.

Similar observations were reported by the Russian scientist Irena Ermakova, who fed GM soy to female rats.<sup>a</sup> Other studies have shown the deleterious effects of GM pollen on Monarch butterflies and caterpillars as well as other insects.

Hellmich *et al.* (2001) conducted laboratory tests to establish the relative toxicity of Bt toxins and pollen from Bt corn in monarch larvae. They found that first instars are sensitive to CryIAb and CryIAc proteins, and that pollen contaminants can dramatically influence larval survival and weight gain and produce spurious results.

The biologist Michelle Marvier and her colleagues (2007) at Santa Clara University in California, USA, examined the ecological

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<sup>a</sup> Irina Ermakova's research was critically examined in the following paper: Marshall, A. (2007) GM soybeans and health safety — a controversy reexamined. *Nat Biotechnol* **25**: 981–987.

consequences of transgenic Bt in a meta-analysis of 42 field experiments. They indicated that nontarget invertebrates are generally more abundant in Bt cotton and Bt maize fields than in nontransgenic fields managed with insecticides; however, in comparison with insecticide-free control fields, certain nontarget taxa are less abundant in Bt fields. The central goal of this study was to quantitatively investigate whether changes in invertebrate abundance were statistically significant. The failure to find significant differences in previous studies was generally viewed as a signal of environmental safety, but they were often based on small samples. Whether statistically significant differences in abundance truly indicate ecologically significant changes is not clear. The study revealed, however, that Bt crop acreage has less insect biodiversity than untreated fields. It is unclear whether the reduced abundance of various groups (coleopterans, hemipterans, and hymenopterans) is due to direct toxicity or is a response to reduced availability of prey in Bt crops.