Genetic Engineering and Food Security: Ecological and Livelihood Issues

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As we say goodbye to the 20th century, we can look back with pride and satisfaction on the revolution that our farm men and women have brought about in our agricultural history. In 1969 I wrote in the Illustrated Weekly of India about the role our farm families played in initiating the Wheat Revolution in India: "Brimming with enthusiasm, hard-working, skilled and determined, the Punjab farmer has been the backbone of the revolution. Revolutions are usually associated with the young, but in this revolution, age has been no obstacle to participation. Farmers, young and old, educated and uneducated, have easily taken to the new agronomy. It has been heart-warming to see young college graduates, retired officials, ex-armymen, illiterate peasants and small farmers queuing up to get the new seeds. At least in the Punjab, the divorce between intellect and labour, which has been the bane of our agriculture, is vanishing."

While we can and should rejoice about the past achievements of our farmers, scientists, extension workers, and policymakers, there is no room for complacency. We continue to face several problems:

- First, increasing population leads to increased demand for food and reduced per capita availability of arable land and irrigation water.
- Second, improved purchasing power and increased urbanization lead to higher per capita food grain requirements due to an increased consumption of animal products.
- Third, marine fish production is becoming stagnant.
- Fourth, there is increasing damage to the ecological foundations of agriculture, such as land, water, forests, biodiversity, and the atmosphere, and there are distinct possibilities for adverse changes in climate and sea level.
- Finally, while dramatic new technological developments are taking place, particularly in biotechnology, environmental and social implications are yet to be fully understood.

Because land and water for agriculture are diminishing resources, there is no option but to produce more food and other agricultural commodities from less arable land and irrigation water. In other words, the need for more food has to be met through higher yields per units of land, water, energy and time. We need to examine how science can be mobilized to raise further the biological productivity ceiling without associated ecological harm. Scientific progress on the farms, as an "*ever-green revolution*," must emphasize that the productivity advance is sustainable over time since it is rooted in the principles of ecology, economics, social and gender equity, and employment generation.

The dimensions of the challenges faced by those involved in developing scientific strategies and public policies for sustainable food security are best defined in some statistics on India, which now has a population of one billion. In global terms, India today has 16 percent of human population, 15 percent of farm animal population, 2 percent of the geographical area, 1 percent of rainfall, 0.5 percent of forests, and 0.5 percent of grazing land.

The Green Revolution has so far helped to keep the rate of growth in food production above the population growth rate. The Green Revolution was, however, the result of public good research, supported by public funds. The emerging gene revolution, by contrast, is spearheaded by proprietary science and can come under monopolistic control. How can we take the fruits of the gene revolution to the unreached?

Meeting the Challenges Ahead

The Gene Revolution

Mendel's laws of genetics were rediscovered in 1900. Mendel had published his work on inheritance patterns in pea in 1865, but it took 35 years for others to grasp their significance. Since 1900, we have witnessed steady progress in our understanding of the genetic makeup of all living organisms ranging from microbes to man. A major step in human control over genetic traits was taken in the 1920s when Muller and Stadler discovered that radiation can induce mutations in animals and plants.

In the 1930s and 1940s, several new methods of chromosome and gene manipulation were discovered, such as the use of colchicine to achieve a doubling in chromosome number, commercial exploitation of hybrid vigor in maize and other crops, use of chemicals such as nitrogen mustard and ethyl methane sulphonate to induce mutations and techniques like tissue culture and embryo rescue to get viable hybrids from distantly related species. The double helix structure of DNA (deoxyribonucleic acid), the chemical substance of heredity, was discovered in 1953 by James Watson and Francis Crick. This triggered explosive progress in every field of genetics.

As we approach the end of the 20th century, we see a rapid transition from Mendelian to molecular genetic applications in agriculture, medicine, and industry. This brief capsule of genetic progress from 1900 to 1999 adequately stresses that knowledge and discovery represent a continuum, with each generation taking our understanding of the complex web of life to a higher level. It would therefore be wrong to worship or discard experimental tools or scientific innovations because they are either old or new.

Just as it took 35 years for biologists to understand the significance of Mendel's work, it may take a couple of decades more to understand fully the benefits and risks associated with genetically improved foods. It would be prudent to apply scientific and precautionary principles in areas of human health and environmental safety.

The 1990s have seen dramatic advances in our understanding of how biological organisms function at the molecular level, as well as in our ability to analyze, understand, and manipulate DNA molecules, the biological material from which the genes in all organisms are made. The entire process has been accelerated by the Human Genome Project, which has poured substantial resources into the development of new technologies to work with human genes. The same technologies are directly applicable to all other organisms, including plants. Thus, the new scientific discipline of *genomics* has arisen, which has contributed to powerful new approaches in agriculture and medicine, and has helped to promote the biotechnology industry.

Several large corporations in Europe and the United States have made major investments to adapt these technologies to produce new plant varieties of agricultural importance for large-scale commercial agriculture. The same technologies have equally important potential applications to address food security and poverty of people in developing countries.

Work in India has shown that genetic modification can do immense good in agriculture and food security. The 21st century may witness changes in temperature, precipitation, sea level, and ultraviolet b radiation, as a result of global warming. These changes in climate are expected to adversely affect India and sub-Saharan Africa. All human-induced calamities affect adversely the poor nations and the poorest among all nations the most. This led us to initiate an anticipatory research program to breed salt-tolerant varieties of rice and other crop plants in coastal areas, in order to prepare for seawater intrusion into farmland as a result of an eventual rise in sea level. The donor of salt tolerance was a mangrove species belonging to the family *Rhizophoraceae.* Transferring genes for tolerance to salinity from mangrove tree species to rice or tobacco is an impossible task without recourse to recombinant DNA experiments. This demonstrates the immense benefits that can accrue from genomics and molecular breeding.

Concerns

What then are the principal concerns? In industrial countries, the major concerns relate to the impact of genetically improved organisms (GIOs) on human health and the environment. These food and environmental safety concerns have been well documented and are widely known. The food and environmental scientists of developing countries are equally concerned about the food and environmental safety aspects of GIOs. The ethical and social issues relating to GM crops were dealt with in detail in a report published by the Nuffield Council on Bioethics in May 1999. What issues concern the public and professionals in developing countries?

The first issue of concern is biosafety. Why are large biotechnology companies averse to the labeling of GM foods? In spite of over three years of intensive discussion in meetings sponsored by the Secretariat of the Convention on Biological Diversity (CBD), the negotiations broke down at Cartagena, Colombia, in February 1999. Thus, there is as yet no internationally agreed biosafety protocol, as called for under Article 19 of CBD. The absence of such a protocol will hurt the private sector the most.

There are other issues of concern to the general public in India. First, India is a land of small farm holdings. There are now 106 million operational holdings in the country, and about 75 percent of them are one hectare or less. India has 25 percent of the global farming community, and farming provides a livelihood to nearly 66 percent of the population. There is concern that expansion of proprietary science and shrinking of "public good" research supported from public funds may lead to a situation where the technologies of the future remain in the hands of a few transnational corporations. Only resource-rich farmers may have access to them, thereby widening further the gap between the rich and poor. This could accelerate social disintegration.

Second, monopolistic control over crop varieties could lead to a situation where large areas are covered by very few genetic strains or hybrids. It is well known that genetic homogeneity enhances genetic vulnerability to biotic and abiotic stresses. Biotechnology companies are therefore recommending resistance management strategies, such as growing 30-40 percent non-Bt (*Bacillus thuringiensis*) corn with Bt-corn (see Gould and Cohen this volume). What will happen to the livelihood of farm men and women operating smallholdings with institutional credit and with no crop insurance, if GM corn, soybean, rice, potato or other crops are affected by serious diseases as a result of the breakdown of resistance? Will the companies agree to compensate them for the loss? This problem could become even more serious if companies incorporate genetic use restriction mechanisms, known popularly as "terminator" genes in the new varieties. Small farmers could then experience "genetic enslavement" since their agricultural destiny could be in the hands of a few companies if they have to purchase new seeds each year, similar to conventional hybrid seed.

A third issue relates to the potential impact of GM foods on biodiversity. This has two dimensions. The first deals with the replacement of numerous local cultivars with one or two new varieties, which could lead to genetic erosion. Modernization of agriculture has resulted in a narrowing of the base of food security, both in terms of the number of species constituting the food basket and the number of genetic strains cultivated (see NRC 1989, 1996). Local cultivars have often been the donors of many useful traits, including resistance to pests and diseases. Under small farm conditions, every farm is a genetic garden, comprising several annual and perennial crops, and several varieties of each crop. The need of the hour is to enlarge the food basket and not shrink it further.

The second dimension is equity in benefit sharing between biotechnologists and the primary conservers of genetic resources and the holders of traditional knowledge. The primary conservers have so far remained poor, while those who use their knowledge (for example, the medicinal properties of plants) and material become rich. This has resulted in accusations of *biopiracy*. It is time that genetic engineers and others promote and find ways to implement genuine *biopartnerships* with the holders of indigenous knowledge and traditional conservers of genetic variability, based on principles of ethics and equity in benefit sharing.

Unless R&D efforts on GM foods are based on principles of *bioethics, biosafety, biodiversity conservation, and biopartnerships,* there will be serious public concern in India, as well as many other developing countries, about the ultimate nutritional, social, ecological, and economic consequences of replacing numerous local varieties with a few new genetically improved crop varieties. To derive benefits from genetic engineering without undue risks, every nation should set up a multistakeholder Commission for Genetic Modification.

The Ecotechnology Revolution

Knowledge is a continuum. There is much to learn from the past in terms of the ecological and social sustainability of technologies. At the same time, new developments have opened up new opportunities to develop technologies that can lead to high productivity without adverse impact on the natural resources base. Blending traditional and frontier technologies leads to the birth of *ecotechnologies* with combined strength in economics, ecology, equity, employment, and energy.

In water harvesting and sustainable use, for example, there are many lessons to be learned from the past. In the desert area of Rajasthan, India, drinking water is available even in areas with 100 mm annual rainfall, largely because women are continuing to harvest water in simple structures called *kunds*. In contrast, drinking water is scarce during summer months in some parts of northeast India, with an annual rainfall of 15,000 mm. There is need therefore to conserve traditional wisdom and practices, which are tending to become extinct. The decision of the World Intellectual Property Organization (WIPO) to explore the intellectual property needs, rights, and expectations of holders of traditional knowledge, innovations, and culture is an important step in widening the concept of intellectual property rights (IPR). Principles of ethics and equity demand that this invaluable component of IPR be included when the TRIPs (Trade-related Intellectual Property Rights) agreement of the World Trade Organization (WTO) comes up for review. FAO has been a pioneer in the recognition of the contributions of farm families in genetic resources conservation and enhancement by promoting the concept of *Farmers' Rights*. Like WIPO, UPOV (Union for the Protection of New Varieties of Crops) should also undertake the task of preparing an integrated concept of breeders' and farmers' rights and assisting countries in developing equitable and effective *sui generis* systems for the protection of new plant varieties, as is required for all members of WTO (Barton, 1999; Leisinger, 1999).

Science and Basic Human Needs

The 20th century produced an impressive array of accomplishments in nearly every field of science and technology. The last part of the century was particularly rich in innovations in biotechnology, and information and space technologies. Such advances have had a beneficial impact on human food and health security. The global population was only 940 million in 1798 when Malthus expressed his apprehensions about human capacity to achieve a balance between food production and population. Human numbers reached 6 billion in 1999, and once in every12 years another billion will be added, if current growth rates continue in developing countries. Science-based technologies supported by appropriate public policies are responsible for food famines becoming rare. The famine of food at the level of an individual today is mostly due to inadequate purchasing power arising from a famine of jobs or employment opportunities.

In spite of an impressive stockpile of scientific discoveries and technological innovations, poverty and social and gender inequities are increasing. According to the World Bank, 1.3 billion people lived on less than US$1 per day and another 3 billion lived on less than US$2 per day in 1993. Nearly 1.5 billion of the world population of 6 billion will live in severe poverty at the dawn of the new millennium. Illiteracy, particularly among women, is still high in many developing countries. It is not only in opportunities for education that children of many developing countries remain handicapped, but even more alarming, in opportunities for the full expression of their innate genetic potential for physical and mental development. Between 25 and 50 percent of children born in South Asian countries are characterized by low birth weight (LBW), caused by maternal and fetal undernutrition and malnutrition. The UN Commission on Nutrition in a recent report has warned about the serious consequences of LBW for both brain development in the child, as well as the level of health in later life.

New technologies supported by appropriate services and public policies have helped to prove doomsday predictions wrong, and have led to the agricultural revolution (the Green Revolution) becoming one of the most significant of the scientific and socially meaningful events of the 20th century. Four thousand years of wheat cultivation led to Indian farmers producing 6 million metric tons of wheat in 1947. The Green Revolution in wheat helped to surpass in 4 years the production accomplishments of the preceding 4000 years, thus illustrating the power of synergy between science and public policy.

There are uncommon opportunities now to harness the power of such synergy to address contemporary development issues such as the growing rich-poor divide, feminization of poverty, famine of jobs, human numbers exceeding the population-supporting capacity of ecosystems, climate change, and loss of forests and biodiversity. Whether in economics or in ecology, experience has shown that a trickle-down approach does not work. Fortunately, modern information technology provides opportunities to reach the unreached. *Virtual colleges*, computer-aided and internet-connected, linking scientists and women and men living in poverty can be established at local, national, and global levels to launch a knowledge and skill revolution. This will help to create better awareness of the benefits and risks associated with genetically improved organisms, so that both farmers and consumers will get better insights into the processes leading to the creation of novel genetic combinations.

The future of small farm families will depend on *precision agriculture*, which involves the use of the right inputs at the right time and in the right way. Biotechnology will play an important role in the major components of precision farming: integrated gene management, soil health care, efficient water management, integrated pest management, integrated nutrient supply, and efficient postharvest management. Ecotechnology-based precision farming can help to cut costs, enhance marketable surplus, and eliminate ecological risks. This is the pathway to an ever-green revolution in small-farm agriculture. This is why increased public support to both the CGIAR and NARS is important for strengthening health and food security.

Conclusion

The industrial revolution in Europe marked the transition to a world where technology became a major causal factor in the prosperity gap between developing and industrial nations. How can we now enlist technology as an ally in the movement for social, gender and economic equity in an era of expanding proprietary science? Obviously, public good research supported from public funds must be stepped up. The following indicator of measuring the value of development efforts proposed by Mahatma Gandhi is the most meaningful yardstick for determining priorities in scientific research designed to help in meeting basic human needs: "*Recall the face of the poorest and the weakest man whom you have seen, and ask yourself, if the steps you contemplate are going to be of any use to him. Will he gain anything by it? Will it restore to him control over his own life and destiny?*"

If biotechnology research can be promoted keeping in mind the guideline Gandhi gave, it will become a powerful tool in ensuring sustainable food security in the world.

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