Editor's Choice

Ending World Hunger. The Promise of Biotechnology and the Threat of Antiscience Zealotry

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During the 20th century, conventional breeding produced a vast number of varieties and hybrids that contributed immensely to higher grain yield, stability of harvests, and farm income. Despite the successes of the Green Revolution, the battle to ensure food security for hundreds of millions miserably poor people is far from won. Mushrooming populations, changing demographics, and inadequate poverty intervention programs have eroded many of the gains of the Green Revolution. This is not to say that the Green Revolution is over. Increases in crop management productivity can be made all along the line: in tillage, water use, fertilization, weed and pest control, and harvesting. However, for the genetic improvement of food crops to continue at a pace sufficient to meet the needs of the 8.3 billion people projected to be on this planet at the end of the quarter century, both conventional technology and biotechnology are needed.

WHAT CAN WE EXPECT FROM BIOTECHNOLOGY?

The majority of agricultural scientists, including myself, anticipate great benefits from biotechnology in the coming decades to help meet our future needs for food and fiber. The commercial adoption by farmers of transgenic crops has been one of the most rapid cases of technology diffusion in the history of agriculture. Between 1996 and 1999, the area planted commercially with transgenic crops has increased from 1.7 to 39.9 million ha (James, 1999). In the last 20 years, biotechnology has developed invaluable new scientific methodologies and products, which need active financial and organizational support to bring them to fruition. So far, biotechnology has had the greatest impact in medicine and public health. However, there are a number of fascinating developments that are approaching commercial applications in agriculture.

Transgenic varieties and hybrids of cotton, maize, and potatoes, containing genes from *Bacillus thuringiensis* that effectively control a number of serious insect pests, are now being successfully introduced commercially in the United States. The use of such varieties will greatly reduce the need for insecticides. Considerable progress also has been made in the development of transgenic plants of cotton, maize, oilseed rape, soybeans, sugar beet, and wheat, with tolerance to a number of herbicides. The development of these plants could lead to a reduction in overall herbicide use through more specific interventions and dosages. Not only will this development lower production costs; it also has important environmental advantages.

Good progress has been made in developing cereal varieties with greater tolerance for soil alkalinity, free aluminum, and iron toxicities. These varieties will help to ameliorate the soil degradation problems that have developed in many existing irrigation systems. These varieties will also allow agriculture to succeed in acidic soil areas, thus adding more arable land to the global production base. Greater tolerance of abiotic extremes, such as drought, heat, and cold, will benefit irrigated areas in several ways. We will be able to achieve more crop per drop by designing plants with reduced water requirements and adopting between-crop/water management systems. Recombinant DNA techniques can speed up the development process.

There are also hopeful signs that we will be able to improve fertilizer-use efficiency by genetically engineering wheat and other crops to have high levels of Glu dehydrogenase. Transgenic wheats with high Glu dehydrogenase, for example, yielded up to 29% more crop with the same amount of fertilizer than did the normal crop (Smil, 1999).

Transgenic plants that can control viral and fungal diseases are not nearly as developed. Nevertheless, there are some promising examples of specific virus coat genes in transgenic varieties of potatoes and rice that confer considerable protection. Other promising genes for disease resistance are being incorporated into other crop species through transgenic manipulations.

I would like to share one dream that I hope scientists will achieve in the not-too-distant future. Rice is the only cereal that has immunity to the *Puccinia* sp. of rust. Imagine the benefits if the genes for rust immunity in rice could be transferred into wheat, barley, oats, maize, millet, and sorghum. The world could finally be free of the scourge of the rusts, which have led to so many famines over human history.

The power of genetic engineering to improve the nutritional quality of our food crop species is also immense. Scientists have long had an interest in improving maize protein quality. More than 70 years ago, researchers determined the importance of certain amino acids for nutrition. More than 50 years ago, scientists began a search for a maize kernel that had higher levels of Lys and Trp, two essential amino acids that are normally deficient in maize. Thirty-six years ago, scientists at Purdue University (West Lafayette, IN) discovered a floury maize grain from the South American Andean highlands carrying the opaque-2 gene that had much higher levels of Lys and Trp. But as is all too often the case in plant breeding, a highly desirable trait turned out to be closely associated with several undesirable ones. The dull, chalky, soft opaque-2 maize kernels yielded 15% to 20% less grain weight than normal maize grain. However, scientists from the International Maize and Wheat Improvement Center (Mexico City) who were working with opaque-2 maize observed little islands of translucent starch in some opaque-2 endosperms. Using conventional breeding methodologies supported by rapid chemical analysis of large numbers of samples, the scientists were able to slowly accumulate modifier genes to convert the original soft opaque-2 endosperm into vitreous, hard endosperm types. This conversion took nearly 20 years. Had genetic engineering techniques been available then, the genes that controlled high Lys and Trp could have been inserted into high-yielding hard-endosperm phenotypes. Thus through the use of genetic engineering tools, instead of a 35-year gestation period, quality protein maize could have been available to improve human and animal nutrition 20 years earlier. This is the power of the new science.

Scientists from the Swiss Federal Institute of Technology (Zurich) and the International Rice Research Institute (Los Baños, The Philippines) have recently succeeded in transferring genes into rice to increase the quantities of vitamin A, iron, and other micronutrients. This work could eventually have profound impact for millions of people with deficiencies of vitamin A and iron, causes of blindness and anemia, respectively.

Because most of the genetic engineering research is being done by the private sector, which patents its inventions, agricultural policy makers must face a potentially serious problem. How will these resource-poor farmers of the world be able to gain access to the products of biotechnology research? How long, and under what terms, should patents be granted for bioengineered products? Furthermore, the high cost of biotechnology research is leading to a rapid consolidation in the ownership of agricultural life science companies. Is this consolidation desirable? These issues are matters for serious consideration by national, regional, and global governmental organizations.

National governments need to be prepared to work with and benefit from the new breakthroughs in biotechnology. First and foremost, governments must establish regulatory frameworks to guide the testing and use of genetically modified crops. These rules and regulations should be reasonable in terms of risk aversion and implementation costs. Science must not be hobbled by excessively restrictive regulations. Since much of the biotechnology research is under way in the private sector, the issue of intellectual property rights must be addressed and accorded adequate safeguards by national governments.

STANDING UP TO THE ANTISCIENCE CROWD

The world has or will soon have the agricultural technology available to feed the 8.3 billion people anticipated in the next quarter of a century. The more pertinent question today is whether farmers and ranchers will be permitted to use that technology. Extremists in the environmental movement, largely from rich nations and/or the privileged strata of society in poor nations, seem to be doing everything they can to stop scientific progress in its tracks. It is sad that some scientists, many of whom should or do know better, have also jumped on the extremist environmental bandwagon in search of research funds. When scientists align themselves with antiscience political movements or lend their name to unscientific propositions, what are we to think? Is it any wonder that science is losing its constituency? We must be on guard against politically opportunistic, pseudo-scientists like the late Trofim D. Lysenko, whose bizarre ideas and vicious persecution of his detractors contributed greatly to the collapse of the former USSR.

We all owe a debt of gratitude to the environmental movement that has taken place over the past 40 years. This movement has led to legislation to improve air and water quality, protect wildlife, control the disposal of toxic wastes, protect the soils, and reduce the loss of biodiversity. It is ironic, therefore, that the platform of the antibiotechnology extremists, if it were to be adopted, would have grievous consequences for both the environment and humanity. I often ask the critics of modern agricultural technology: What would the world have been like without the technological advances that have occurred? For those who profess a concern for protecting the environment, consider the positive impact resulting from the application of science-based technology. Had 1961 average world cereal yields (1,531 kg/ha) still prevailed, nearly 850 million ha of additional land of the same quality would have been needed to equal the 1999 cereal harvest (2.06 billion gross metric tons). It is obvious that such a surplus of land was not available, and certainly not in populous Asia. Moreover, even if it were available, think of the soil erosion and the loss of forests, grasslands, and wildlife that would have resulted had we tried to produce these larger harvests with the older, low-input technology! Nevertheless, the antibiotechnology zealots continue to wage their campaigns of propaganda and vandalism.

One particularly egregious example of antibiotechnology propaganda came to my attention during a recent field tour to Africa. An article in The Independent (Walsh, 2000) newspaper from London, entitled "America Finds Ready Market for Genetically Modified Food: the Hungry," is accompanied by a ghastly photograph depicting a man near death from starvation, lying next to food sacks. The caption below reads "Sudanese man collapsing as he waits for food from the UN World Food Program."

The article's author, Declan Walsh, writing from Nairobi, implies that there is a conspiracy between the U.S. government and the World Food Program (WFP) to dump unsafe, American, genetically modified crops into the one remaining unquestioning market: emergency aid for the world's starving and displaced. I, for one, take heartfelt umbrage against this insult to the WFP, whose workers and collaborators helped feed 86 million people in 82 countries in 1999. The employees of the WFP are among the world's unsung heroes, who struggle against the clock and under exceedingly difficult conditions to save people from famine. Their achievements, dedication, and bravery deserve our highest respect and praise.

In his article, Walsh quotes several critics of the use of genetically modified food in Africa. Elfrieda Pschorn-Strauss, from the South African organization Biowatch, says "The US does not need to grow nor donate genetically modified crops. To donate untested food and seed to Africa is not an act of kindness but an attempt to lure Africa into further dependence on foreign aid." Dr. Tewolde Gebre Egziabher of Ethiopia states that "Countries in the grip of a crisis are unlikely to have leverage to say, 'This crop is contaminated; we're not taking it.' They should not be faced with a dilemma between allowing a million people to starve to death and allowing their genetic pool to be polluted." Neither of these individuals offers any credible scientific evidence to back their false assertions concerning the safety of genetically modified foods. The WFP only accepts food donations that fully meet the safety standards in the donor country. In the United States, genetically modified foods are judged to be safe by the Department of Agriculture, the Food and Drug Administration, and the Environmental Protection Agency and thus they are acceptable to the WFP. That the European Union has placed a 2-year moratorium on genetically modified imports says little per se about food safety, but rather it says more about consumer concerns, largely the result of unsubstantiated scare mongering done by opponents of genetic engineering.

Let's consider the underlying thrust of Walsh's article that genetically modified food is unnatural and unsafe. Genetically modified organisms and genetically modified foods are imprecise terms that refer to the use of transgenic crops (i.e. those grown from seeds that contain the genes of different species). The fact is that genetic modification started long before humankind started altering crops by artificial selection. Mother Nature did it, and often in a big way. For example, the wheat groups we rely on for much of our food supply are the result of unusual (but natural) crosses between different species of grasses. Today's bread wheat is the result of the hybridization of three different plant genomes, each containing a set of seven chromosomes, and thus could easily be classified as transgenic. Maize is another crop that is the product of transgenic hybridization (probably of teosinte and Tripsacum). Neolithic humans domesticated virtually all of our food and livestock species over a relatively short period 10,000 to 15,000 years ago. Several hundred generations of farmer descendents were subsequently responsible for making enormous genetic modifications in all of our major crop and animal species. To see how far the evolutionary changes have come, one only needs to look at the 5,000-year-old fossilized corn cobs found in the caves of Tehuacan in Mexico, which are about one-tenth the size of modern maize varieties. Thanks to the development of science over the past 150 years, we now have the insights into plant genetics and breeding to do purposefully what Mother Nature did herself in the past by chance.

Genetic modification of crops is not some kind of witchcraft; rather, it is the progressive harnessing of the forces of nature to the benefit of feeding the human race. The genetic engineering of plants at the molecular level is just another step in humankind's deepening scientific journey into living genomes. Genetic engineering is not a replacement of conventional breeding but rather a complementary research tool to identify desirable genes from remotely related taxonomic groups and transfer these genes more quickly and precisely into high-yield, high-quality crop varieties. To date, there has been no credible scientific evidence to suggest that the ingestion of transgenic products is injurious to human health or the environment. Scientists have debated the possible benefits of transgenic products versus the risks society is willing to take. Certainly, zero risk is unrealistic and probably unattainable. Scientific advances always involve some risk that unintended outcomes could occur. So far, the most prestigious national academies of science, and now even the Vatican, have come out in support of genetic engineering to improve the quantity, quality, and availability of food supplies. The more important matters of concern by civil societies should be equity issues related to genetic ownership, control, and access to transgenic agricultural products.

One of the great challenges facing society in the 21st century will be a renewal and broadening of scientific education at all age levels that keeps pace with the times. Nowhere is it more important for knowledge to confront fear born of ignorance than in the production of food, still the basic human activity. In particular, we need to close the biological science knowledge gap in the affluent societies now thoroughly urban and removed from any tangible relationship to the land. The needless confrontation of consumers against the use of transgenic crop technology in Europe and elsewhere might have been avoided had more people received a better education about genetic diversity and variation. Privileged societies have the luxury of adopting a very low-risk position on the genetically modified crop issue, even if this action later turns out to be unnecessary. But the vast majority of humankind, including the hungry victims of wars, natural disasters, and economic crises who are served by the WFP, does not have such a luxury. I agree with Mr. Walsh when he speculates that esoteric arguments about the genetic make-up of a bag of grain mean little to those for whom food aid is a matter of life or death. He should take this thought more deeply to heart.

We cannot turn back the clock on agriculture and only use methods that were developed to feed a much smaller population. It took some 10,000 years to expand food production to the current level of about 5 billion tons per year. By 2025, we will have to nearly double current production again. This increase cannot be accomplished unless farmers across the world have access to current high-yielding crop production methods as well as new biotechnological breakthroughs that can increase the yields, dependability, and nutritional quality of our basic food crops. We need to bring common sense into the debate on agricultural science and technology and the sooner the better!

CONCLUSIONS

Thirty years ago, in my acceptance speech for the Nobel Peace Prize, I said that the Green Revolution had won a temporary success in man's war against hunger, which if fully implemented, could provide sufficient food for humankind through the end of the 20th century. But I warned that unless the frightening power of human reproduction was curbed, the success of the Green Revolution would only be ephemeral.

I now say that the world has the technology that is either available or well advanced in the research pipeline to feed a population of 10 billion people. The more pertinent question today is: Will farmers and ranchers will be permitted to use this new technology?

Extreme environmental elitists seem to be doing everything they can to derail scientific progress. Small, well-financed, vociferous, and antiscience groups are threatening the development and application of new technology, whether it is developed from biotechnology or more conventional methods of agricultural science.

I agree fully with a petition written by Professor C.S. Prakash of Tuskegee University, and now signed by several thousand scientists worldwide, in support of agricultural biotechnology, which states that no food products, whether produced with recombinant DNA techniques or more traditional methods, are totally without risk. The risks posed by foods are a function of the biological characteristics of those foods and the specific genes that have been used, not of the processes employed in their development.

The affluent nations can afford to adopt elitist positions and pay more for food produced by the so-called natural methods; the 1 billion chronically poor and hungry people of this world cannot. New technology will be their salvation, freeing them from obsolete, low-yielding, and more costly production technology.

Most certainly, agricultural scientists and leaders have a moral obligation to warn the political, educational, and religious leaders about the magnitude and seriousness of the arable land, food, and population problems that lie ahead, even with breakthroughs in biotechnology. If we fail to do so, then we will be negligent in our duty and inadvertently may be contributing to the pending chaos of incalculable millions of deaths by starvation. But we must also speak unequivocally and convincingly to policy makers that global food insecurity will not disappear without new technology; to ignore this reality will make future solutions all the more difficult to achieve.

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