

Feeding the Developing World in the Next Millennium: A Question of Science?

Alexander F. McCalla and Lynn R. Brown

Science played a major role in meeting the challenge of producing enough food to feed the additional billions of people added in the past 40 – 50 years. The Green Revolution in rice and wheat was responsible for securing major yield increases in those grains. In the period 1960 -90 global cereal production doubled, per capita food availability increased 37 percent, per capita calories available per day increased 35 percent, and real food prices declined 50 percent. This impressive global aggregate performance, however, masks considerable regional differences. In sub-Saharan Africa, in the same period, per capita food availability, and consequently per capita calorie availability, decreased due to sometimes negative growth rates in agricultural production and continuing high population growth rates. Increases in per capita calorie availability were also more muted in South Asia, home to about 140 million malnourished children under 5 years old.

Despite good global agricultural performance with respect to yield, the numbers of people undernourished fell by only 80 million, from 920 million to 840 million between the end of the 1960s and the early 1990s. As with the increases in per capita calorie availability, there were regional differences. While the share of the undernourished in East Asia declined markedly, the share in sub-Saharan Africa more than doubled. To make matters worse the numbers suffering from a deficiency in at least one micronutrient doubled between the 1960s and the early 1990s. Compared to the doubling in cereal production,

the reductions in malnutrition were less impressive. This implies a lack of access to food on the part of the poor. This is of more concern today since the rate of yield increases, the source of most agricultural production growth outside of sub-Saharan Africa, has slowed considerably. If the rate of growth of food production relative to population and income growth falls, then price increases will likely follow, further compromising the ability of the poor to obtain food.

Production Challenges

In the first 25 - 30 years of the next millennium the world's population will increase by about 2 billion people. Most of this increase, about 95 percent, will take place in the developing world. This in itself is a challenge – feeding an extra 2 billion people while hopefully reducing the more than three-quarters of a billion people who do not have enough to eat today. We also must address the issue of more than 2 billion people who are deficient in one or more micronutrients such as iron.

The production challenge we face in the next millennium is not unprecedented. Between 1975 and now we have added close to 2 billion people to the world's population and production more than kept pace. Enough food was produced to feed everyone if it had been more equitably distributed. Poverty is the key reason why people do not have enough to eat. Over 1.2 billion people live on less than US\$1 a day and a further 1.6 billion live on less than US\$2.

The production challenge is more complicated, however, if we recognize two additional issues: the location of population growth and urbanization. At least 90 percent of the growth in population will occur in countries located between the tropics of Cancer and Capricorn. The question is Where will the food to feed them come from? In the last doubling of world grain supplies, the share of total grain production traded remained stable at around 10 percent. Stated another way, on average 90 percent of the world's food consumption takes place in the country where the food is produced. If the trend continues, then most of the food production must come from within the countries where the additional people will live. In other words, 90 percent of the increased food needed must be grown in farming systems prevalent in tropical countries. This area includes all of Latin America except for the southern cone of Argentina, Chile and Uruguay, all of Central America, and most of Mexico: all of Africa except the North Africa region and South Africa; the southern half of India and all of Southeast Asia including Indonesia. In these humid, sub-humid, and semi-arid tropical regions farming systems are highly complex, with heterogeneous mixes of annual plants, livestock, and trees. These are systems about which we are not knowledgeable. Most farmers are poor, with small landholdings. Productivity is low and agriculture is subject to water, wind, and temperature stresses. They are also the farming systems most likely to be adversely affected by global warming.

So in the next millennium we face a food, feed, and fiber production challenge in highly complex farming systems that will need to be addressed by science. The good news is that this has the potential to be a win-win challenge. Increasing smallholder agricultural productivity in these areas will not only increase food supplies, but also will increase smallholder incomes thereby reducing poverty, increasing food access, reducing malnutrition, and improving living standards of the poor.

Urbanization

There is a second issue - urbanization. During 1975-99 the urban population of developing countries increased by 1.2 billion. In the next 25 years it will increase by 2 billion, essentially doubling

the urban population in just 25 years. Between 1750 and 1850 when industrialization was in full swing in Europe, it took 100 years to add 500 million to the world population. We will add about four times as many people in one-quarter of the time. The size of many of the developing country cities will far exceed most of the largest cities in the industrial countries. These cities will be in countries where agriculture is still the key economic sector. In 2015 Bombay will have over 26 million residents, Lagos 24.6 million, both of them more than double the 1950 population of New York City and far in excess of the predicted New York population in 2015.

Why does urbanization add to the food production challenge? Rural populations in developing countries obtain most of their food from subsistence production or local markets. Urban populations, on the other hand, obtain around 90 percent of their food from the marketplace. In India and China, two countries with the highest absolute numbers of people, indications are that less than 40 percent of rice and wheat production enters the market beyond the localized market at the point of production.

In the next millennium the fact that population growth takes place in urban areas, rather than rural, means that required growth in marketed food surplus in the developing world is increased more than proportionately. Every time a person transfers from a rural area to an urban one, their marketed food supply requirement doubles. Using conservative estimates we calculated that while population growth projected from now until 2025 is 42 percent, the required growth in marketed surplus of grains would be 60 percent.

The production challenge is therefore great because of three things: the absolute increase in population, where it will occur, and the doubling of urban populations. Given constraints on new land availability and increased competition for water, most of the food production increases must come from intensification of agricultural production on existing land. This is where molecular biology must play a role.

The Doubly-Green Revolution

The World Bank's interest in agricultural productivity improvement stems from its commitment to reduce poverty and food insecurity. Some have

criticized the last Green Revolution, arguing that it disproportionately benefited the rich, in the early years, given the necessity for complementary increases in fertilizers, pesticides, and irrigation. It also contributed to environmental degradation in many areas. The next agricultural revolution must learn from the lessons of the past. It must benefit the poor and it must, at best, improve the existing state of the environment and, at worst, do no harm in terms of further environmental degradation. As Conway (1997) pointed out, the next technology-driven revolution must be doubly green – it must increase food production at a faster rate than in recent years and do it in a sustainable manner without significantly damaging the environment. It should also improve rural incomes and increase accessibility to food by the poor.

Biotechnology has the potential to contribute substantially to this objective, but it is controversial. The early days of the Green Revolution likely did not garner as much media interest despite producing genetically improved organisms. Genetic manipulation is not new. Traditional plant selection and breeding have occurred since the beginning of crop production, resulting in genetically improved organisms. Humans are also genetically improved organisms. Modern biotechnology has been used successfully in agricultural research institutes around the globe, including the centers of the Consultative Group on International Agricultural Research. Uncontroversial techniques include tissue culture, gene mapping, and molecular markers, which are used to improve the efficiency of plant breeding. A recent advance using biotechnology, by the West Africa Rice Development Association, has resulted in a successful cross of a traditional African rice with a high-yielding Asian variety. An exciting development from this work is the creation of a new plant type that can, during its early stages of growth, shade out weeds, similar to the African variety, but has the high yield capacity of Asian rice. In essence the best characteristics of both rice types have been combined, including drought tolerance, disease and pest resistance, and high yields.

The Role of Science

Although media controversy has talked of bio-

technology in general, in essence the concern has largely focused on the transfer of genes between species as opposed to genetically improved organisms within the same genotype. The focus so far of much the commercial development of new crop varieties in industrial countries has been on introducing traits for herbicide tolerance and pest resistance in a few crops (rapeseed, corn, and soybean) by insertion of single genes. The *Bacillus thuringiensis* (Bt) gene from bacteria has been inserted in some crops to function as a pesticide. Little attention has been focused, for example, on micronutrient improvement.

Recent research in Switzerland, funded by the Rockefeller Foundation, shows the potential of modern biotechnology to address developing country micronutrient malnutrition problems. A gene that enhances vitamin A production was inserted into rice using a gene from a daffodil, and in a separate experiment, the bioavailability of iron for human consumption was also increased by introduction of a gene from a french bean. The potential of these advances is enormous. More than 2 billion people are anemic due to iron deficiency. In developing countries, 180 million children die annually from diseases linked to vitamin A deficiency, especially in Asia, where poor children are weaned on rice gruel.

The World Bank is committed to assisting developing countries develop the capacity to make fully informed decisions, including an assessment of the risks and benefits, of the new technological advances afforded by the biological revolution. It is important that developing countries not be left behind, nor their needs ignored in the process of technological innovation.

Public and Private Sector Roles

The Green Revolution took place mainly in public sector research establishments, in an era of open access to genetic resources. Today's biotechnology revolution is taking place largely in the private sector with associated intellectual property protection of emerging technologies. This intellectual property protection is important because it allows companies to recoup in the marketplace the often high R&D costs to develop these new products. The private sector likely will not undertake high-cost R&D without either a functioning marketplace and/or intellectual

property protection. This explains why little private sector research is done on developing country food crops such as sorghum, millet, and cassava.

We need to explore ways to encourage such research by lowering the relative costs of R&D. We propose several options. The first is active public – private sector partnerships in research for developing country food crops. This benefits both parties through increasing the availability of crop germplasm to the private sector, and ensuring attention to the crops most important to poor farmers in developing countries. Intellectual property rights protection needs to be carefully explored in such partnerships. Two such activities deserve special mention. One is the work of Novartis Foundation on sorghum and millet in Africa. The other is the Donald Danforth Plant Science Center jointly funded by Monsanto, The State of Missouri, The Missouri Botanical Gardens, the University of Missouri, the University of Illinois, and Purdue University. Support from the State of Missouri is in the form of tax credits.

This leads to the question of whether tax concessions for such R&D activities should be further explored. Currently most of the multinational life science companies are located within the OECD. One incentive scheme could be tax concessions from host governments for R&D specific to developing country food crops, associated with some form of nonexclusive intellectual property protection. A second suggestion is the medical sector models whereby WHO, the World Bank, and other development agencies are collaborating with pharmaceutical companies in the development of new vaccines against major tropical diseases.

A third suggestion is the establishment of a global competitive grants research facility for R&D on developing country food crops, with nonexclusive intellectual property protection.

Why would companies want to undertake research for which their intellectual property protection was nonexclusive? First, the R&D could lead to new enabling technologies, which they could incorporate in R&D activities on crops other than developing country food crops, and which could have intellectual property protection on the final product. Second, increasing the productivity of developing country agriculture will reduce poverty and lead to agricultural commercializa-

tion, thus creating future competitive market opportunities for other commercial product lines.

Risks

Biotechnology has the potential to contribute to the solution of problems of food insecurity and malnutrition in developing countries. Use of biotechnology, however, could create potential export trade problems for developing countries, given the differing opinions regarding food safety and biosafety in industrial countries. This may lead to the development of non tariff barriers to trade, which developing countries have less ability and resources to address in the international arena. Therefore, it is important that the risks and benefits of any new technology be carefully evaluated. This should be done in both global and national open fora, ensuring that the risks and benefits to all potential beneficiaries are recognized and considered.

It is here that there may be an increasing role for CGIAR centers. Development of new transgenic varieties of developing country food crops is likely to fall outside present food and environment safety testing in industrial countries. Consumption patterns may render developed country biosafety systems less relevant. The lack of an export market for many of these food crops may also leave food safety testing outside of Codex. As well, many of these food crops are not consumed in industrial countries and so they would not have been tested for human consumption there.

For the poorest developing countries, biosafety regulatory systems are limited. If we succeed in getting increased public and private sector investment on the problems important in developing country food crops, then there will be a need to ensure independent testing with regard to human health and environmental safety. The CGIAR centers could potentially support countries in these evaluations. CGIAR centers already have partnerships with NARS to ensure improvement of new crop varieties for developing country agroecological needs. This role could be extended into capacity-building with regard to developing biosafety regulatory systems in conjunction with organizations such as Codex, OECD, UNIDO, and UNEP. Although new transgenic crop varieties are only grown at

present in a few developing countries, media attention has ensured that safety concerns have been well publicized worldwide. Many consumers may know more about the perceived problems than they do about what biotechnology is and its possible benefits.

Conclusion

Biotechnology is one tool in our arsenal for feeding the world in the future. It is a solution not without problems, but it is one we cannot afford to ignore. We have fallen behind in educating consumers about the potential of biotechnology and in reassuring them about safety concerns. We could take some lessons from the pharmaceutical sector, where new drugs are introduced on a regular basis. We would submit that no new drug is absent of all risk, but careful evaluation through extensive clinical trials indicates that the benefits outweigh the risks when taken under prescribed conditions. Likewise there is no such thing as 100 percent safe food in today's world, and no one

would claim such. There were 6.5 million cases of food poisoning in the United States of America in 1992, resulting in 9,000 fatalities. We need to fully assess the risks and benefits of all "new" foods, and when the benefits far outweigh the risk we need to move ahead. Incentives are needed for research attention to developing country food crops. Without them poor farmers and consumers in developing countries will not have access to, and benefit from, these new technologies that would allow them to increase their productivity.

If we turn our backs on modern biotechnology we may exacerbate malnutrition and micronutrient deficiency problems in developing countries. We need to move forward with both good science and effective public education.

Reference

Conway, G. 1997. *The Doubly Green Revolution - Food for all in the 21st Century*. Harmondsworth, U.K.: Penguin Books.