Summary

From the Green to the Gene Revolution—
A 21st Century Challenge

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Extending the Green Revolution

Science and technology has had its greatest impact on the lands best suited to agriculture. Over the past 50 years, the world's farmers have been able to triple world cereal production—from 650 million tons to 1,900 million with only a 10 percent increase in total cultivated cereal area. If we had tried to produce the world cereal harvest of 2000 using the agricultural technology of 1950, we would have needed an additional 1.1 billion ha of land, of the same quality, over and above the 660 million ha that were actually used. Too often, the environmental critics of modern agriculture fail to see these very beneficial aspects to producing more food, feed and fiber on the lands best suited for these uses, so that other lands can be spared for other uses.

Between 1965 and 200, the area in developing Asian countries planted to new high-yielding wheat and rice varieties increased from zero to 170 million ha. The new seeds were the catalyst for a doubling in irrigated area, a 35-fold increase in fertilizer use, and a 20-fold increase in the use of agricultural machinery, and more than a three-fold increase in cereal production—from 309 to 962 million tons. Without these gains, what would have happened to the Asian population, which grew from 1.6 to 3.5 billion people over this period? We should also remember that it was the Green Revolution that permitted the industrialization of Asia that began a decade later.

Despite the successes of the Green Revolution, the battle to ensure food security for hundreds of millions miserably poor people is far from won. Enormous challenges lie ahead to ensure that the projected world population in 2030 of around 9 billion people is adequately and equitably fed, and in environmentally sustainable ways. Moreover, hundreds of millions of small farmers must be taken off the land and into other jobs in rural industries and to urban centers, so that those that stay in farming can obtain sufficient incomes to provide suitable livelihoods and to invest in land improvements, new technologies and farm machinery.

Over the next 50 years, it is likely that the world food supply will have to double, driven strongly by rapidly growing animal feed use and meat, eggs and milk consumption. With the exception of acid-soil areas in South America and Africa, the potential for expanding the global land area is limited. Future expansions in food production must come largely from land already in use. Eighty percent of future increases in world food supply in all likelihood must come from lands already under cultivation. This will require substantial increases in crop yield potential, not only in the cereals but in legumes and roots and tubers.

Of the world's 800 million hungry people, roughly 50 percent live in marginal lands and depend upon agriculture for their livelihoods. These food-insecure households face frequent droughts, degraded lands, remoteness from markets, and poor market institutions. Investments in science, infrastructure and resource conservation are needed to increase productivity and lower their production risks. Some of the problems farmers in marginal lands face will be too formidable for science to overcome. However, significant improvements should be possible. Biotechnology can play a major role in developing new crop varieties with greater tolerance to pests and diseases, drought, and with higher nutritional content. Of course, biotechnology is only a new tool within comprehensive plant breeding programs; conventional breeding still has a major role to play in crop improvement.

Africa is the Greatest Challenge

Africa is the biggest food security challenge we face, although there is still too much hunger in Asia and among indigenous people in Latin America. A twin-track anti-hunger strategy is needed—first, a productivity-led agricultural growth component and second, safety net programs to assist the chronically hungry. The depth of the poverty traps in Africa is such that much great amounts of foreign development assistance are needed. In effect, we need a 21st Century Marshall Plan for Africa.

Why hasn't a Green Revolution taken off in Africa? I don't think the reason is one of technology, although Asia certainly had more of its farmlands under irrigation. I think the principal difference between Asia and sub-Saharan Africa is the infrastructure. One World Bank estimate predicts that it might take another 20 years for Africa to reach the road density that India had in 1960. This is unacceptable. Adequate transport is central to commercial agriculture and rural development. Roads also bring indirect benefits—schools, clinics, transport, and improved communications between different ethic groups. They are a tremendous catalyst for positive change.

Agricultural Challenges in Asia

As I look to the challenges confronting cereal production in Asia over the next 20 years, my concerns revolve around two issues—one is how to increase farmer yields, especially in areas where food crop yields are already high. The second is how agricultural policy can improve on the declining income status of small farmers. Key to improving productivity and profits will be land consolidation, so that the average farm size of practicing farmers becomes larger. This will require successful programs to develop many more off-farm employment opportunities, so that the percentage of the population engaged in agriculture can decline. This implies substantial investments in rural education, health care and infrastructure, so that economies can continue to diversify and generate new areas of employment for the surplus populations leaving the farm.

In crop management in Asia, productivity gains can be made all along the line—in tillage, water and moisture control, fertilization, weed and pest control, and harvesting. Crop productivity depends both on the yield potential of the varieties and the crop management employed to enhance input and output efficiency.

Important yield gains can still be obtained in all of the cereals through implementing improved soil fertility management strategies, especially in the more intensively cultivated areas. Changes in cropping patterns are likely to occur in Asian agriculture. Maize, for example, will replace paddy rice production in some areas. All of us need to heed von Liebig's "Law of the Minimum" and to find the ways to diagnose and remedy the varying nutrient-deficiency situations. Phosphorus and potassium are becoming increasingly deficient in Asian soils, as are various secondary and micronutrients. Diagnostic tools and more intensive training of farmers and extension workers are needed to recognize and pinpoint soil nutrient deficiencies, and permit the type of precision farming that high-yielding areas need to move to higher levels of productivity.

Improving nitrogen efficiency, which is especially low in irrigated rice, would be a major research breakthrough, not only to increase yields and reduce production costs, but also to reduce adverse environmental consequences from nutrient leaching and runoff. Various techniques and products have been identified to improve N efficiency. More of these measures need to be put into commercial use.

Conservation tillage (no-tillage, minimum tillage) is spreading rapidly around the agricultural world, and now covers more than 100 million ha. Asia is rapidly becoming part of this boom. Nearly 3 million ha in the irrigated Indo-Gangetic plains are now planted using conservation tillage. This system can greatly reduce the turnaround time on lands that are double- and triple-cropped annually, especially rotations like rice/wheat and cotton/wheat. This can lead to higher yields and lower production costs.

Integrated Pest Management (IPM) systems, especially in rice and cotton, is another success story in parts of Asia, most notably Indonesia. This experience suggests that IPM technology can have a substantial beneficial impact in future years in reducing pesticide loads, increasing profits, and protecting the environment.

China is projected to have a population of 1.6 billion by 2030. Moreover, it is predicted that more than 300 million formerly rural people will migrate to urban areas over this 25 year period. The food, feed, and fiber demand of China's larger and wealthier population is likely to double by mid-Century while the arable land area is likely to fall by 20 percent. Using current technology, China will be unable to meet the projected demand, even with significant increases in importation of food and feeds, which are inevitable and quite reasonable to expect, given China's emergence as an industrial exporting power. To maintain desirable levels of national production, new agricultural science and technology will be critical to achieving this objective, Far-reaching policy reforms are also needed in agricultural tax policy, land tenure, and farmer education. Chinese farmers need a greater sense of ownership if they are to preserve land fertility, control soil and water erosion, and reduce pollution. Larger tracts of land, more amenable to mechanization will also be required.

Indian agriculture also must go through a major transformation, if past productivity gains are to be duplicated. Expect important changes in the prevailing cropping patterns and crop management systems, especially in the irrigated areas. In the Indo-Gangetic plains, irrigated winter maize production is likely to become increasingly important and to displace wheat and rice to some extent. A shift to higher value export crops in the irrigated areas is also quite likely. Precision farming practices are needed in the high potential areas, especially in soil fertility and pest management and in water use efficiency. The research and development challenges of the more marginal production areas also need to be addressed. Drought tolerance should be a major germplasm development goal.

Water Resource Development

The UN's 1997 Comprehensive Assessment of the Freshwater Resources of the World estimates that, by the year 2025, as much as two-thirds of the world's population could be under water-stress conditions (WMO, 1997). Given these trends, we need to rethink our attitudes about water and move away from thinking of it as a free good. Pricing water delivery closer to its real costs is a necessary step to improving use efficiency. Farmers and irrigation officials (and also urban and industrial consumers) will need incentives to save water. Moreover, management of water distribution networks, except for the primary canals, should be decentralized and turned over to farmers.

There are many technologies for improving the water use efficiency in agriculture. Wastewater can be treated and used for irrigation, especially important for peri-urban agriculture, which is growing rapidly around many of the world's mega-cities. New crops and/or new improved varieties requiring less water, more efficient crop sequencing, and timely planting, can also achieve a significant saving in water use. Proven technologies are also available that save water, reduce soil salinity, and increase water productivity (yield per unit of water used). Various new precision irrigation systems—like drip and sprinkler systems—are available that will supply water to plants only when they need it. Planting on raised beds uses water more efficiently, especially in irrigated areas where savings of 25-30 percent are possible over current practices. Conservation tillage with crop residue mulches also is a water-harvesting technology that can lead to significant yield increases in areas prone to drought. In the 21st century will need to bring about a "Blue Revolution" to complement the so-called "Green Revolution" of the 20th century. In the new Blue Revolution, water-use productivity must be wedded to land-use productivity. New science and technology must lead the way.

What to Expect from Biotechnology

Over the last 20 years, biotechnology based upon recombinant DNA has developed invaluable new scientific methodologies and products for food and agriculture. Recombinant DNA methods have enabled breeders to select and transfer single genes, not only reducing the time needed in conventional breeding to eliminate undesirable genes but also allowing breeders access to useful genes from other distant species. So far, agricultural biotechnology has mainly conferred producer-oriented benefits, such as resistance to pests, diseases, and herbicides. But many consumer-oriented benefits, such as improved nutritional and other health-related characteristics, are likely to be realized over the next 10 to 20 years.

Despite formidable opposition in some circles to transgenic crops, commercial adoption by farmers of new GM varieties has been one of the most rapid cases of technology diffusion in the history of agriculture. Between 1996 and 2005, the area planted to transgenic crops has increased from 1.7 to 90 million ha, and will likely surpass 100 million ha in 2006. Herbicide resistance is revolutionizing soybean production. Genes from a soil bacterium, ***Bacillus thuringiensis***, or Bt, confers excellent resistance to several classes of damaging insects in maize, soybeans and cotton.

The Bt cotton story is especially impressive. Some nine million hectares and six million small-scale farmers in China, South Africa, and India are now growing Bt cotton, greatly improving their yields and profitability, and significantly reducing their use of insecticides. This is a technological revolution that Africa can ill afford to miss.

Public Research Systems Under Threat

Today, the world's wheat farmers face a dangerous situation. For the last 53 years we've had no major change in stem rust organism any place in the world. But in 1999, first reported in Uganda, then in Kenya and now in Ethiopia, a new race of stem rust has evolved that is capable of severely damaging perhaps half of the world's bread wheat.

The publicly funded international disease screening and testing system that existed 25 years ago has broken down, partly a victim of the malaise that has led to steady declines in real public sector research funding. We better wake up before it's too late.

Despite the formidable—yet achievable—challenges to meet the Millennium Development Goals, look at where the world's governments spend too much their money—US$ 900 billion annually on armament and military, and too little on social and economic development.

At the other extreme of the spectrum, the world still has close to 900 million adults who are illiterate—and nearly twice as many women illiterate as men—and 150 million primary school-age children still not in school. This is appalling in this day and age. What a waste of human talent!

Lest we forget, as the late Lord John Boyd Orr, the first director general of FAO so aptly said, "You can't build peace on empty stomachs," to which I add, "or human misery."