

V USING BIOTECHNOLOGY TO ADDRESS POVERTY REDUCTION AND FOOD SECURITY PROBLEMS IN ASIA

A. Linkage Between Biotechnology and Poverty Reduction and Food Security

Agricultural biotechnology will contribute to poverty reduction and food security if scientists can develop technologies to increase quality and yields of food crops, and the technologies are adopted by small farmers. For this to happen, biotechnology R&D will have to meet four conditions:

- (i) It must address both the problems of small farmers in rainfed areas where most of the poor live, and those of small farmers in irrigated areas, which provide the bulk of food grain supply in Asia.
- (ii) It must focus on crops, livestock, and fish commonly grown by small farmers. Major crops are rice, tropical maize, wheat, sorghum, millet, banana, cassava, groundnut, oilseed, potato, and sweetpotato. Biotechnology R&D should also focus on high value cash crops (e.g., cotton, soybean, and vegetables) that can increase the incomes of small farmers through crop diversification. The prospect for improving these crops is bright due to the large demand for them in urban areas and in international markets. Fish and livestock (cattle, sheep, goats, pigs, and chickens) are also important.
- (iii) The technology to be developed and delivered to small farmers must be simple, low cost, and carry little or no risks to human health and the environment. As in the case of the Green Revolution, the most effective strategy to increase food production is through improved seeds that possess high yield potential, fertilizer responsiveness, resistance to pests and diseases, good agronomic characteristics, and good nutritional quality.
- (iv) Biotechnology development should be accompanied by favorable policy environment; good governance; investments

in rural infrastructure; agricultural research and extension; and credit and marketing.

B. Why Invest in Agricultural Biotechnology?

In much of Asia, yields of major food grains are stagnant or declining in the face of population increases. Pests and diseases cause substantial preharvest and postharvest losses of crops, livestock, and fish. Solutions to many of these problems may lie in the various applications of modern biotechnology.

The use of molecular markers to tag specific traits is accelerating the breeding of new varieties of plants and animals. New understanding of plant and animal genes through genomics may offer ways of increasing crop yields.

These new developments when used in conjunction with developments in the physical and social sciences, offer more sustainable means for obtaining necessary productivity increases that are less dependent on environmentally damaging inputs of chemical fertilizers and pesticides. Given appropriate policies and necessary human and financial resources, modern biotechnology could make an extremely important contribution to future agricultural growth.

During the next 25 years, Asia will need a Second Green Revolution, often called Biorevolution or Doubly Green Revolution. Conway (1997) pointed out that the next technology-driven revolution must be doubly green—it must increase food production at a faster rate than in recent years without significantly damaging the environment. It must also increase incomes and increase access to food by the poor. The differences between the Green Revolution and Biorevolution are described in Table 5.1. Compared to the Green Revolution of the 1970s, Biorevolution will be characterized by the following features:

- (i) Potentially many crops (particularly high value and specialty crops), will be affected as well as livestock and aquaculture.
- (ii) Potentially all areas, both irrigated and rainfed, will benefit from biotechnology R&D.
- (iii) Technology development and dissemination will substantially involve the private sector with the public sector playing the role of facilitator and regulator.

- (iv) Many processes and products will be patentable and protectable.
- (v) Capital costs of research will be high.
- (vi) Molecular and cell biology expertise will be required in addition to expertise in conventional plant breeding and other agricultural sciences

Modern biotechnology (genetic engineering) is not a silver bullet for achieving food security, but used in conjunction with other techniques it may be a powerful tool in the fight against poverty and food insecurity (Persley and Lantin 2000). Other approaches are available and should be used. Narrowing the yield gap between those obtained from farmers' fields and those from experiment stations using the current technologies is just one example. However, there is concern that some conventional alternatives will not be able to produce the desired results within a limited time. The advantage of modern biotechnology rests on the speed at which desired crop varieties are produced. In some cases, the desirable genetic combination of traits is simply not possible through common breeding methods, and can be done only through genetic engineering.

To increase food production by at least 40 percent within the next 25 years, Asian countries not only have to move toward the best technological frontier (to push farmers' yields to the optimum level), but keep moving the technological frontier itself. As long as product safety, environmental and ethical concerns, and IP issues are adequately addressed, modern agricultural biotechnology has the potential to significantly increase the quantity and quality of the food supply for developing countries.

C. Applying Biotechnology in Resource Poor Areas

The resource-poor, rainfed areas in Asia are home to many poor people, and their population is growing rapidly. Although migration may sometimes be the only viable livelihood strategy, in many such areas sustainable intensification of agriculture may be the best way to achieve poverty reduction and food security. Development policy has often neglected these areas characterized by poor soils, shorter growing seasons, lower and uncertain rainfall, and little infrastructure or access to markets. Yield increases usually lag behind population growth. Efforts by poor farmers to expand cultivation onto new lands to eke out survival often

Table 5.1: Characteristics of the Green Revolution and the Biorevolution

Characteristics	Green Revolution	Biorevolution
Crops affected	Mainly wheat and rice	Potentially all crops, including cereals, vegetables, fruits, export commodities, and specialty crops
Other products affected	None	Animal and fish products Processed food products
Areas affected	Irrigated and other favorable areas	Potentially all countries and all areas, including marginal lands
Technology development and dissemination	Largely public or quasi-public sector	Substantial private sector involvement
Proprietary considerations	Patents and plant variety protection not important	Many processes and products patentable and protectable
Capital costs of research	Relatively low	Relatively high
Research skills required	Conventional plant breeding and other agricultural sciences	Molecular and cell biology expertise plus conventional plant breeding skills and expertise in other agricultural sciences
Crops displaced	None, but traditional varieties and land races replaced by high-yielding varieties	None, but traditional varieties and land races replaced by high-yielding varieties
Access to information	Relatively easy	Restricted due to IPR

IPR = intellectual property right.

lead to deforestation and erosion of fragile highland soils. That in turn threatens hydropower, road, and irrigation infrastructure in the lowlands. Policies and investments are required that can achieve food security in ways that protect natural resources, thereby breaking the vicious cycle of poverty, low productivity, and environmental degradation. Creation of nonfarm, rural jobs will also be important (ADB 2000b).

Sizeable investments in biotechnology in Asia have been made in rainfed areas, although DMCs continue to give high priority to irrigated agriculture. Irrigated areas produce 75 percent of total cereal production in Asia. Many IARCs such as the Asian Vegetable Research and Development Center, CIMMYT, CIP, ICRISAT, ILRI, and IRRI; and most DMCs have invested heavily in R&D on orphan crops such as rice, tropical maize, sorghum, potato, banana, groundnut, and sweetpotato.

D. Applicability of Biotechnology to Specific Agricultural Objectives

In Asia, biotechnology has been applied mainly to develop improved varieties adapted to specific environments. Specific areas where new applications of biotechnology could address poverty reduction and food security are summarized as follows:

- (i) **Increasing Productivity and Stability of Crops in Rainfed and Marginal Environments.** Producing more food on the same area of cultivated land would reduce pressure to expand cultivated areas to forests and marginal areas. Broadening tolerance of existing HYV cereals for drought, flooding, salinity, heavy metals, and other abiotic and biotic stresses would increase yields in rainfed areas. CIMMYT and IRRI, in cooperation with NARSs in different countries, are focusing their efforts to develop HYVs of rice and maize for rainfed areas.
- (ii) **Improving Water Use Efficiency in Crops.** Future availability of water for agriculture is a major issue. By 2020, there may be a water crisis in Asian agriculture (ADB 2000c). Crops with higher water use efficiency and tolerance for drought would be an advantage. With the completion of the rice genome, scientists will be able to identify genes responsible for drought tolerance.

- (iii) **Integrated Pest Management (IPM) Strategies to Reduce Pesticide Use.** The insecticides now used in many developing countries are often older, broad spectrum, acutely toxic compounds. Many are now banned in industrial countries except for export. They are a significant health hazard to farmers and farm workers throughout Asia. Over 80 percent of total pesticide use in Asia is on cotton, rice, and vegetables.

In the past, governments encouraged the use of chemical pesticides as part of a yield-increasing package of farm inputs, and some governments still subsidize pesticides. The need is now recognized for more sustainable approaches to IPM to reduce losses to pests without harmful side effects on human health and the environment. New pest- and disease-resistant crops, produced with the aid of modern biotechnology, may be important components of IPM strategies (Persley 1996).

Early applications are being seen in the use of novel sources of resistance (Bt genes) to control insect pests on maize and cotton. New pest-resistant cotton varieties are being grown widely in the PRC by 3 million farmers covering 500,000 ha (Pray 2000). Similar cotton varieties are undergoing field tests in India, Indonesia, and Thailand. Genetically modified maize resistant to insect pests is being tested in the Philippines.

- (iv) **Increasing Disease Resistance in Crops.** Biotechnology applied to disease resistance in crops would be especially valuable for combating diseases in tropical environments that have not been controlled by conventional means. These include important diseases such as downy mildew of maize; bacterial blight and blast of rice, papaya ringspot virus; banana bunchy top virus; and bacterial wilt of tomato, eggplant, and potato.
- (v) **Increasing Nutritional Quality.** Enhancing the protein, vitamin, and micronutrient contents of food grains would greatly benefit poor consumers who cannot afford supplementary vitamins and micronutrients. Under the Golden Rice Project, IRRI scientists are undertaking biotechnology research to

enhance the vitamin A content of rice by introducing genes from daffodil (IRRI 2001).

- (vi) **Increasing Sustainable Production of Livestock.** Research to increase the productivity and quality of farm animals, especially of dairy cows, small ruminants (sheep and goats), and water buffalo is promising. Vaccines and disease diagnostics for control of epidemic and endemic diseases of livestock are being developed.
- (vii) **Increasing Productivity in Fisheries and Aquaculture.** Development of vaccines and disease diagnostics for control of epidemic and endemic diseases of shrimp in Thailand is a good example of where modern biotechnology has been used successfully (Box 3).

Box 5.3: The Success Story of Shrimp Biotechnology in Thailand

Shrimp is one of the top 10 exports for Thailand, generating about \$1.5 billion in annual export earnings. In 1999, there were about 25,000 shrimp farms, producing 240,000 t valued at 87 billion baht (\$1.8 billion), and employing about 130,000 people.

Diseases are a major constraint in the production of cultivated shrimp. In 1994, the white spot syndrome virus became a major disease in the PRC, and quickly spread to the rest of Asia, including Thailand. The disease caused a sharp drop in shrimp production in the PRC from 155,000 t to 35,000 t, a decline of about 77 percent. National Center for Genetic Engineering and Biotechnology (BIOTEC) quickly supported research at the Universities of Chulalongkorn and Mahidol to develop DNA probe technology for the rapid detection of major shrimp pathogens. Rapid diagnostic reagents were quickly developed, the technology was transferred to the shrimp industry, and the virus was effectively controlled. It is estimated that shrimp biotechnology research and development has yielded a net benefit of about \$1 billion since 1996. That constitutes a return on investment of 5,000 times in a single year, since the total cost of the biotechnology was only \$200,000.

Source: Morakot Tanticharoen (2000).

E. Benefits from Agricultural Biotechnology

Realized or potential benefits of agricultural biotechnology can be categorized as economic, social, and environmental. A large share of the benefits are concentrated in industrialized countries, where a diversity of applications are widespread in human and animal health care and in many aspects of food production and processing. Some of the potential benefits of biotechnology are shown in Table 5.2.

As the first transgenic biotechnology product was not commercialized until 1996, little quantitative analysis has been publicly available until recently. The studies published by ISAAA (James 1997, 1998, and 2000) have helped fill the gap, at least with respect to transgenic crops. ISAAA analyzed the global status of transgenic crops, including the area planted and the value of the market for transgenic seed, which was estimated between \$2.7 billion and \$3.0 billion in 1999. The studies show that the economic benefits were fairly evenly distributed between the companies that developed the technology and the farmers growing transgenic crops.

ISAAA studies have also demonstrated positive environmental impacts. In the cases of herbicide-tolerant soybean and herbicide-tolerant canola, herbicide use was considerably reduced even though weeds were better controlled, and yields increased significantly. In the cases of Bt maize, cotton, and potatoes, targeted insect pests were effectively controlled and yields were increased. Insecticide use for nontargeted insects was also reduced.

1. Economic Benefits in Developing Countries

Few published analytical studies have attempted to assess the impact of biotechnology in developing countries. Ex-ante studies (Qaim 1999) on transgenic pest- or virus-resistant sweetpotato in Kenya and on transgenic virus-resistant potato in Mexico suggest substantial benefits for both producers and consumers. They point out, however, that smallholders will fully realize benefits only with improved farm-level management and more efficient seed distribution.

The introduction of pathogen-free banana planting material in Kenya illustrates the benefits that accrue to small-scale farmers, mainly woman. Yield increases from the new material have been substantial; in some cases yields almost doubled. This example is significant in that it involved community groups and farmers in the development and field-testing. By

Table 5.2: Potential Benefits from Plant Genetic Engineering

Benefit	Example
Increasing crop productivity	<ul style="list-style-type: none"> Improving growth rate Altering ratio of usable product (e.g., increased proportion of seed in rice plants)
Increasing crop quality	<ul style="list-style-type: none"> Improving nutritional quality (e.g., specific vitamin contents, type and content of fiber, fat components, amino acids) Removing food contaminants and toxins (e.g., aflatoxins) Improving storage properties (e.g., fresh vegetables and fruits)
Environmental adaptation	<ul style="list-style-type: none"> Making crops plants better adapted to changing environments
Broadening stress tolerance	<ul style="list-style-type: none"> Making plants more resistant to drought, flooding, salinity, heavy metals, pollution
Increasing disease and pest resistance	<ul style="list-style-type: none"> Selecting resistant varieties (e.g., using molecular techniques to insert antiviral or antibacterial genes from other species) Hybridizing crops with wild relatives (e.g., use of cellular methods for rapid screening for desired phenotypes)
Agrochemical reduction	<ul style="list-style-type: none"> Breeding crop varieties resistant to specific herbicides (e.g., glyphosate-resistant soybean, through insertion of a bacterial gene that reduces sensitivity to herbicide)
Production of nonedible substances	<ul style="list-style-type: none"> Use of food crops to produce nonedible products (e.g., medicinal products and proteins, fuel alcohol, industrial oils) Using food crops for polymer and bioplastic production
Use of new raw materials	<ul style="list-style-type: none"> Production of single cell (e.g., growing bacteria on methanol for animal feed, growing mycoprotein from fungi and wastes from pulp and paper industry)

Source: Macer (1997).

the time the new planting material was available commercially, the benefits of the technology had already been demonstrated to farmers, with the result that initially demand exceeded supply. The project won the science and technology prize in a Japan/World Bank-sponsored network of environmentally beneficial development projects. The Kenyan experience is highly relevant to Asia.

2. Benefits in Asia

A number of biotechnology applications are widespread in Asia. These include biofertilizers and biopesticides, and products from tissue culture and micropropagation (banana, coconut, maize, potato, cassava). They also include diagnostics, vaccines, and embryo transfer for livestock.

An ex-post evaluation on the impact of a transgenic crop at the farm level in Asia analyzed the impact of Bt cotton in the PRC (Pray et al. 2000) A sample of 283 cotton farmers from five counties of Hebei and Shandong provinces was studied. The key findings were (i) the cost to produce 1 kg of cotton was reduced by 20- 30 percent, depending on the variety and site, and (ii) net income and returns to labor of all the Bt varieties were superior to the non-Bt varieties. Smaller farms and those farms that had lower incomes consistently derived larger increases in net income than larger farms and those with higher incomes.

The use of Bt cotton substantially reduced farmers' use of pesticides, usually from 12 sprays per season to 3 or 4. The study also found some preliminary evidence of positive impact on farmers' health.

An ex-ante study on the impact of the introduction of biotechnology for the reduction of corn-borer infestation in the Philippines (Gonzales 1999) has postulated three kinds of benefits. First, the introduction of transgenic Bt maize would enhance the competitiveness of the Philippines from the point of view of import substitution and export prospects. Second, it would increase farmers' incomes. Third, it would reduce pesticide use.

F. Weighing Risks and Benefits of Biotechnology

The evidence thus far available suggests potential economic, social, and environmental benefits from the use of biotechnology. It also

suggests benefits for both food and export crops, for commercial and small farmers, and for consumers in the form of nutrition-enhanced products. The potential benefits will be realized only if a number of conditions are met:

- (i) Public institutions will need to play a key role in directing the research agenda toward social and equity goals.
- (ii) Complementarity between the public and private sectors, in both R&D and in technology development and delivery, needs to be maximized so that public investment and research is focused on those areas not of interest to the private sector.
- (iii) Governments must be committed to developing technologies for the public good to ensure that the poor, including women, have access to the new technology.

The benefits and risks of biotechnology need to be assessed on a case-by-case basis. The uncertainties and the risks are yet to be fully understood, and the benefits are not yet fully exploited. It seems important not to deny people access to new biotechnology, so long as they are fully informed of the potential risks and benefits in making their choices. We have an ethical imperative not only to keep the technology portfolio open to biotechnology and genetic engineering, but also not to lose time. Every minute lost, every decision delayed, means more deaths from starvation and malnutrition (Leisinger 2000).