Agricultural Biotechnology, Poverty Reduction, and Food Security

A Working Paper
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FOREWORD

Recent breakthroughs in biotechnology have led to rapid progress in understanding the genetic basis of living organisms, and the ability to develop products and processes useful to human and animal health, food and agriculture, and industry. In agriculture, there is increasing use of biotechnology for genetic mapping and marker-assisted selection to aid more precise and rapid development of new strains of improved crops and livestock. Other biotechnology applications such as tissue culture and micropropagation are being used for the rapid multiplication of disease-free planting materials. New diagnostics and vaccines are being widely adopted for the diagnosis, prevention, and control of animal and fish diseases. Many of these developments have taken place mainly in the United States and other developed countries. But in recent years several developing countries in Asia including People's Republic of China, India, Indonesia, Malaysia, Pakistan, Philippines, and Viet Nam have begun to invest heavily in biotechnology.

Biotechnology has given us a new tool to improve food security and reduce poverty. This development is encouraging since the Green Revolution technologies, which have doubled food production and reduced poverty during the past three decades, have already run their course in much of Asia. Conventional breeding, widely used during the Green Revolution era, no longer provides needed breakthroughs in yield potentials, nor the solution to the complex problems of pests, diseases, and drought stress. That is particularly true in the rainfed areas where the poor are concentrated. The challenge is how to use new developments in biotechnology together with information technology and new ways of managing knowledge to make the complex agricultural systems of Asia more productive and sustainable.

The development of agricultural biotechnology is perceived by some as posing considerable risks to human health and the environment. Most of the debate on biotechnology has been focused on genetically modified organisms (GMOs). The public debate surrounding GMOs has heightened concerns that genetic engineering may in the long run be harmful to human health and the environment unless effective regulatory frameworks are implemented. Indeed, the public and private sectors must manage the introduction and use of biotechnology to maximize benefits and minimize risks.

Given these developments, the Asian Development Bank (ADB), together with the Australian Centre for International Agricultural Research and the Australian Agency for International Development, undertook a study to examine the opportunities and risks of using biotechnology in reducing poverty and achieving food security in Asia. The study is designed to provide the latest information on the effective and safe use of biotechnology for the benefit of Asian farmers. As a premier development institution, ADB is responsible for assisting its developing member countries (DMCs) to deal with potential risks of biotechnology and providing information on various issues biotechnology relating.

The team effort used ADB staff, international experts, and an external review panel under the guidance of the Directors, Agriculture and Social Sectors Departments for Regions East and West. A working group made up of ADB staff reviewed the work of the international experts. A panel of external experts from international organizations was constituted to review and comment on the approach, methods, and results of the study.

The results and recommendations of the study were presented for comment at an international workshop held 15-17 January 2001 in Manila. Some 60 persons attended, including senior government officials and representatives of international agencies, nongovernment organizations, private sector companies, and funding agencies. The revised report is being published by ADB as a Working Paper to provide a basis for future discussion between ADB and its DMCs on how to use biotechnology safely and effectively to reduce poverty and increase food production in Asia. These findings and recommendations should prove useful to all concerned with improving the economic and social conditions of rural populations in Asia.

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ABBREVIATIONS

ACO	–	1-aminocyclopropane-1-carboxylic acid oxidase
AARD	–	Agency for Agricultural Research and Development
ACIAR	–	Australian Centre for International Agricultural Research
ADB	–	Asian Development Bank
AFLP	–	amplied fragment length polymorphism
AFMA	–	Agriculture, Fisheries Modernization Act
AMBIONET	–	Asian Maize Biotechnology Network
APEC	–	Asia-Pacific Economic Cooperation
ARBN	–	Asian Rice Biotechnology Network
ASEAN	–	Association of Southeast Asian Nations
AusAID	–	Australian Agency for International Development
BBPT	–	Agency for Technology Assessment and Application (Jakarta)
BCC	–	Biotechnology Cooperative Center
BGA	–	blue green algae
BIOBIN	–	OECD's BioTrack Online and UNIDO's BINAS
BIOTEC	–	National Center for Genetic Engineering and Biotechnology (Thailand)
BIOTECH	–	National Institute of Molecular Biology and Biotechnology (Philippines)
Bt	–	*bacillus thuringiensis*
BW	–	bacterial wilt
ccs	–	commercial cane sugar
cDNA	–	complementary DNA
CEMB	–	Centre of Excellence in Molecular Biology
CEPT	–	Common effective preferential tariff
CGIAR	–	Consultative Group on International Agricultural Research
CIAT	–	Centro International de Agricultural Tropical (International Center for Tropical Agriculture)
CIMMYT	–	Centro Internacional de Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center)
CIP	–	Centro Internacional de la Papa (International Potato Center)
CMV	–	cucumber mosaic virus

COGENT	–	Coconut Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center)
CSIR	–	Council of Scientific and Industrial Research
DBT	–	Department of Biotechnology (India)
DMC	–	developing member country
DNA	–	deoxyribonucleic acid
DOA	–	Department of Agriculture
DST	–	Department of Science and Technology (India)
EA	–	executing agency
EBD	–	infectious boval disease
FAO	–	Food and Agriculture Organization
GATT	–	General Agreement on Tariffs and Trade
GE	–	genetically engineered
GEF	–	Global Environment Fund
GIO	–	genetically improved organisms
GM	–	genetically modified
GMAC	–	Genetic Modification Advisory Committee
GMO	–	genetically modified organism
ha	–	hectare
HRD	–	human resource development
HTP	–	high throughput analysis
HYV	–	high-yielding variety
IAEA	–	International Atomic Energy Agency
IARC	–	International Agricultural Research Center
IBS	–	ISNAR Biotechnology Service
ICAR	–	Indian Council of Agricultural Research
ICLARM	–	International Center for Living Aquatic Resources Management
ICMR	–	Indian Council of Medical Research
ICRISAT	–	International Crops Research Institute for the Semi-Arid Tropics
ICSRG	–	International Collaboration for Sequencing the Rice Genome
IFPRI	–	International Food Policy Research Institute
ILRI	–	International Livestock Research Institute
IMBN	–	International Molecular Biology Network
IP	–	intellectual property
IPGRI	–	International Plant Genetic Resource Institute
IPM	–	integrated pest management
IPP	–	intellectual property protection

IPR	–	intellectual property right
IRPA	–	Intensification of Research in Priority Areas
IRRI	–	International Rice Research Institute
ISAAA	–	International Service for the Acquisition of Agri-biotech Applications
ISNAR	–	International Service for National Agricultural Research
LIPI	–	R&D Center for Biotechnology in Bogor
LMO	–	living modified organism
MAS	–	marker-assisted selection
MINFAL	–	Ministry of Food, Agriculture and Livestock
MIT	–	Massachusetts Institute of Technology
MOF	–	Ministry of Finance
MOST	–	Ministry of Science and Technology
MOSTE	–	Ministry of Science, Technology and the Environment (Malaysia)
MTA	–	materials transfer agreement
NAP3	–	Third National Agricultural Policy
NARC	–	National Agricultural Research Center
NARS	–	national agricultural research system
NBC	–	National Biosafety Committee
NBD	–	National Biotechnology Directorate (Malaysia)
NGO	–	nongovernment organization
NIAB	–	Nuclear Institute for Agriculture and Biology
NIBGE	–	National Institute for Biotechnology and Genetic Engineering
NNSFC	–	National Natural Science Foundation of China
NSF	–	National Science Foundation
NPV	–	nuclear polyhedrosis virus
ODA	–	Overseas Development Administration
OECD	–	Organisation for Economic Co-operation and Development
PAEC	–	Pakistan Atomic Energy Commission
PBR	–	plant breeders' right
PCR	–	polymerase chain reaction
PRC	–	People's Republic of China
PRSV	–	papaya ringspot virus
PVP	–	plant variety protection
QTL	–	quantitative trait loci
RAPD	–	randomly amplified polymorphic DNA
RDE	–	National Research, Development and Extension

R&D	–	research and development
rDNA	–	recombinant DNA
RETA	–	regional technical assistance
RF	–	Rockefeller Foundation
RFLP	–	restriction fragment length polymorphism
RM	–	Malaysian ringgit
RNA	–	ribonucleic acid
SNP	–	single nucleotide polymorphisms
SSR	–	simple sequence repeats
STS	–	sequence-tagged sites
t	–	ton
TTDI	–	Thailand Tapioca Development Institute
TRIP	–	Agreement on Trade-Related Aspects of Intellectual Property
UK	–	United Kingdom
UNCED	–	United Nations Conference on Environment and Development
UNDP	–	United Nations Development Programme
UNEP	–	United Nations Environmental Programme
UNICEF	–	United Nations Children's Fund
UNIDO	–	United Nations Industrial Development Organization
UP	–	University of the Philippines
UPLB	–	University of the Philippines in Los Baños
UPOV	–	Union pour la Protection des Obtentions Végétales (International Convention for the Protection of Plant Varieties)
US	–	United States
USA	–	United States of America
USAID	–	United States Agency for International Development
USDA	–	United States Department of Agriculture
WHO	–	World Health Organization
WIPO	–	World Intellectual Property Organization
wss	–	white spot syndrome
wssv	–	white spot syndrome virus
WTO	–	World Trade Organization
YHD	–	yellow head disease

NOTE

In this report, "$" refers to US dollars.

EXECUTIVE SUMMARY

In October 1999, the Asian Development Bank (ADB) approved a strategy to reduce poverty through pro-poor, sustainable economic growth, social development, and good governance. Given the advances in biotechnology during the last decade, the importance of managing the Biotechnology Revolution in agriculture emerged as one of the principal challenges facing Asia in the future. In late 2000, ADB, in cooperation with the Australian Agency for International Development (AusAID) and the Australian Centre for International Agricultural Research (ACIAR) undertook a study on agricultural biotechnology in Asia. The objectives were to: (i) examine the risks and benefits of biotechnology in relation to human health, the environment, and agriculture; (ii) identify measures to minimize adverse impacts; (iii) explore the use of biotechnology to reduce poverty and achieve food security in Asia; and (iv) develop policies and strategies for ADB to support biotechnology in developing countries in Asia. The results of the study are reflected in this Working Paper.

A. Past Success in Reducing Poverty and Improving Food Security

About 900 million people or 75 percent of the world's poor live in Asia. They live on less than $1 a day. About 536 million of them, including 160 million children, are undernourished. These families lack access not only to sufficient money to buy food and other essentials, but also access to adequate schooling, housing, and medical care. For those in rural areas, the environments in which they live are often short of water, fuel, and firewood. Fertile land and water for farming are increasingly scarce. For the poor people in cities, lack of money is the major constraint to obtaining nutritious food.

Although the absolute numbers of people living in poverty in Asia today are unacceptable, the situation could be much worse. In 1970, 60 percent of all Asians lived in poverty; today that figure has been cut to 30 percent. Also, countries such as Bangladesh, the People's Republic of China (PRC), and India have moved from periodic famines to virtual self-sufficiency in food production.

Science and technology underpinned the economic and social gains in Asia over the past 30 years, which in agriculture came to be known as the Green Revolution. Between 1970 and 1995, cereal production in Asia doubled, calorie availability per person increased by 24 percent, and real food prices halved. The key elements in these gains were government policies reflecting the belief that investments in increasing agricultural productivity were a prerequisite to economic development. These national policies were supported by the public and private sectors, and the international community.

This mix of supportive public policies, scientific discoveries, and public and private investments in rural Asia, particularly in irrigation, credit, and farm inputs, led to the substantial reductions in poverty and improved food security realized throughout Asia over the past 30 years. Increased agricultural productivity, rapid industrial growth, and expansion of the nonfarm rural economy have all contributed to almost a tripling of per capita gross domestic production during the period.

B. Present Problems

The intensification of agriculture and the reliance on irrigation and chemical inputs has led to environmental degradation. Much of Asia faces problems of salinity, pesticide misuse, and degradation of natural resources. The Green Revolution technologies were useful in the favorable and irrigated environments. But they had little impact on the millions of smallholders living in rainfed and marginal areas where poverty is concentrated. In addition, there have been declining public investments in the agriculture sector across the region. These factors have been responsible for the decline in annual agricultural growth rates from an average of 3.3 percent during 1977-1986 to about 1.5 percent during 1987-1996.

C. Future Challenges

During the next 25 years, the population in Asia is projected to increase from 3.0 billion to 4.5 billion. The demand for food is predicted to increase by about 40 percent from the present level of 650 million tons. This increase must come from increases in agricultural productivity in favorable areas and in rainfed and marginal areas. They will have to be achieved with less labor, water, and arable land since there is no scope for increasing the cultivated areas. Based on current trends in population and food production in Asia, there is likely to be a large gap between food production and demand by 2025.

Strategies to meet the required increases in food supply include (i) sustainable productivity increases in food, feed, and fiber crops; (ii) reducing chemical inputs of fertilizers and pesticides and replacing them with biologically-based products; (iii) integrating soil, water, and nutrient management; (iv) improving the nutrition and productivity of livestock and controlling livestock diseases; (v) achieving sustainable increases in fisheries and aquaculture production; and (vi) increasing trade and competitiveness in global markets.

The challenge is how to use new developments in modern science (including biotechnology) in concert with information and communications technology, and new ways of managing knowledge, to make the complex agricultural systems of Asia more productive in sustainable ways.

D. Modern Scientific Developments

The pace of change in modern science has led to rapid progress in understanding the genetic basis of living organisms. That has given us the ability to develop new products and processes useful in human and animal health, food and agriculture, and the environment. In agriculture, the use of modern molecular genetics for genetic mapping and marker-assisted selection speed the development of more precise new strains of improved crops, livestock, fish, and trees. Other biotechnology applications such as tissue culture and micropropagation are used for the rapid multiplication of disease-free planting materials of horticultural crops and trees. New diagnostics and animal vaccines are being widely adopted for the diagnosis, prevention, and control of fish and livestock diseases.

The new technologies will greatly increase the efficiency of selection for valuable genes, based on knowledge of the biology of the organism, the function of specific genes, and their role in regulating particular traits. That will enable more precise selection of improved strains by crop scientists. Many of the applications of biotechnology involve the use of improved selection methods for crops and animals bred conventionally. They do not always require the development of transgenic crops and animals or other genetically modified organisms (GMOs).

The advantages of the new techniques of modern biotechnology are that they (i) speed plant and animal breeding, (ii) offer possible solutions to previously intractable problems such as drought tolerance, and (iii) enable the development of new products such as more nutritious food. However, the safety and efficacy of the new products of modern biotechnology in agriculture, particularly the development of transgenic crops and other GMOs, is the subject of often heated public debate. The challenge is how to apply the products of biotechnology safely and effectively for the benefit of small farmers in Asia.

E. Current Status of Agricultural Biotechnology in Asia

Several emerging economies in Asia, including the PRC, India, Indonesia, Malaysia, Pakistan, Philippines, Thailand, and Viet Nam, are making major investments in modern biotechnology to further the aim of improving food security and reducing poverty. In addition, several regional and international programs and a growing number of private sector companies are working on biotechnology.

The PRC is most advanced in the use of genetically modified crops. There are at least 500,000 ha of genetically modified crops grown commercially. Commercial production of transgenic cotton and soybean with resistance to insect pests is expanding. The first contribution of biotechnology toward increasing yields will be realized by decreasing losses from diseases and pests while minimizing the use of pesticides.

National biotechnology programs in Asia are being assisted through various bilateral and multilateral programs. Most support is country-specific and directed toward providing infrastructure, equipment, and postgraduate training. Multilateral assistance comes from ADB, the Food and Agriculture Organization, the United Nations Development Programme, the United Nations Industrial Development Organization, and the World Bank. World Bank projects have supported the extensive development of human resources and infrastructure for biotechnology in India and Indonesia. ADB has provided similar support to Pakistan, Philippines, Sri Lanka, and Thailand, and regional technical assistance to international agricultural research centers (IARCs).

In research and development (R&D), financial assistance also comes from the governments of Australia, Japan, and the United States through their international aid agencies, and from the Rockefeller Foundation. All support the applications of biotechnology through specific projects. In addition, private companies and nongovernment organizations support national or regional activities. Also, several IARCs supported by the Consultative Group on International Agricultural Research, and the Asian Vegetable Research and Development Center are using new biotechnology techniques to increase the productivity of the major cereal, legume, and vegetable crops; characterize and conserve the genetic resources of crops and trees; and improve the health and increase the productivity of livestock and fish.

F. Potential Contribution of Biotechnology Toward Poverty Reduction and Food Security

Agricultural biotechnology is expected to contribute significantly toward poverty reduction and food security in Asia through increased productivity, lower production costs and food prices, and improved nutrition. That is because much of public sector R&D has emphasized simple, low cost technology appropriate for poor farmers in the rainfed and marginal areas, despite human resource and financial constraints that hinder progress. The focus has been on the so-called orphan crops (rice, tropical maize, wheat, sorghum, millet, banana, cassava, groundnut, oilseed, potato, sweetpotato, and soybean) that the private sector has largely ignored because of their low return on investment. Enhancing cooperation between the public and private sectors would speed development.

Modern plant breeding may help to achieve productivity gains, introduce resistance to pests and diseases, reduce pesticide use, improve crop tolerance for abiotic stress, improve the nutritional value of some foods, and enhance the durability of products during harvesting and shipping. Biotechnology may offer cost-effective solutions to vitamin and mineral deficiencies by developing rice varieties that contain vitamin A and minerals. Raising productivity could increase smallholders' incomes, reduce poverty, increase food access, reduce malnutrition, and improve the livelihoods of the poor. In the PRC, cotton farmers that have adopted insect-resistant, transgenic Bt cotton have reduced their use of highly toxic insecticides. That in turn has reduced farmers' crop protection costs and benefited both the environment and public health. A real problem is how to provide adequate incentives for crop breeders to focus on orphan crops and adaptations to difficult environments, which are of greater interest to poor farmers. Public funding and the involvement of international organizations will be crucial to such research.

G. Key Issues

1. Potential Risks of Biotechnology

The public debate on biotechnology has been focused on GMOs, one of the many products of biotechnology. The public perception is that genetically engineered foods and crops may have food biosafety, environmental, socioeconomic, and ethical risks. Some of these risks are genuine and need to be addressed by the public and private sectors to ensure that GMOs are widely accepted. An open, transparent, and inclusive food safety policy and regulatory process is required.

The potential long-term impact of genetically improved foods on human health and the environment is unknown, and requires monitoring and further research. Methods are available to test allergenicity and toxicity of genetically modified foods in humans before approving them for human consumption.

Six environmental safety issues need to be considered when addressing risks posed by the cultivation of genetically modified plants: gene transfer, weediness, trait effects, genetic and phenotypic variability, expression of genetic material from pathogens, and worker safety. The Cartagena Protocol on Biosafety, agreed to by 130 governments in January 2000, specifies obligations for international transfer of living modified organisms. It also sets out means of risk assessment and management, advance informed agreement, technology transfer, and capacity building. The Protocol establishes a Biosafety Clearing-House through which governments signal whether or not they will accept imports of agricultural commodities that include GMOs. Further, it establishes labeling requirements for shipments of commodities that may contain GMOs. Developing countries in Asia will need to strengthen their biosafety regulations and enforcement to ensure that the risks of biotechnology can be minimized. Public awareness activities from the onset of a biotechnology work program can greatly assist in gaining consumer acceptance of biotechnology products.

2. Intellectual Property Management

A set of intellectual property right (IPR) issues is associated with biotechnology. They include (i) lack of access of poor farmers to the new technologies and products, (ii) losses of ownership rights of some developing countries over their own indigenous genetic resources, (iii) lack of incentives for the free flow of technologies and products from developed to developing countries, and (iv) a growing danger that the free flow of agricultural materials between countries will be impeded. The public and private sectors need to manage intellectual property to ensure that IPRs do not exclude developing countries from access to the benefits of new technology.

3. Economic Concentration in Agricultural Biotechnology

Multinational companies in the seeds, agricultural chemicals, pharmaceuticals, and food processing industries in developed countries play a major role in biotechnology research. They have invested heavily in in-house research facilities, commissioned research, taken equity positions in new biotechnology firms, or entered into contractual arrangements with public research institutions or universities. The development of new biotechnology applications in agriculture has become increasingly concentrated in the hands of a decreasing number of companies as a result of mergers and acquisitions. In the short term, most genetically engineered crops will be developed and grown in developed countries by large-scale farmers. Changing patterns of international trade in foods that result from genetic engineering in developed countries could have serious consequences for some developing countries in Asia.

4. Need for Increased Public-Private Sector Collaboration

Public investment in agricultural biotechnology is crucial for achieving future food security and reducing poverty. The private sector is unlikely to undertake much of the R&D needed by small farmers because it sees little potential for return on investment. Accelerated public investments are needed to develop biotechnology applications that address difficult problems in rainfed and marginal areas. And additional private and philanthropic resources are required because most governments in Asia have limited resources to finance biotechnology research. Currently, it is the private sector that has the knowledge, skills, and capital to solve the problems of small farmers. Financial incentives or policy initiatives are essential for increased collaboration in biotechnology R&D between the public and private sectors.

5. Policy and Priority Setting

Considerable biotechnology R&D is already being carried out in Asian countries, particularly in the more developed countries such as PRC, India, Indonesia, Philippines, and Thailand. They and other Asian countries should establish clear policies and priorities in agricultural biotechnology R&D to ensure that the output will contribute significantly toward poverty reduction and food security. Policies will need to take into account (i) the high level of capital and technical skills biotechnology requires, (ii) the often inadequate capacity that constrains public and private biotechnology R&D in developing countries, (iii) the reluctance of the private sector to invest in technology for Asia's poor farmers, (iv) the inherent risks in some uses of biotechnology, and (v) the difficulty of establishing and implementing effective biosafety regimes.

H. Conclusions and Recommendations

The major conclusion of this study is that the governments and funding agencies should continue and increase their investments in biotechnology as a means of achieving their goals of poverty reduction and food security in Asia over the next 25 years. Achieving these goals with presently available technologies will be difficult, given the present trends and challenges facing the rural sector in Asian environments. Accordingly, it is recommended that the following measures be considered by ADB and the governments in the region.

1. General Strategy

To ensure that agricultural biotechnology will contribute to reducing poverty and improving food security in Asia, biotechnology R&D should do the following:

(i) Address the problems of small farmers in the rainfed and marginal areas where most of the poor live, yet not neglect the problems of small farmers in the irrigated areas.
(ii) Focus on economically important orphan crops, high value crops, and livestock to increase their productivity.
(iii) Develop low cost, appropriate technologies for small farmers, particularly the development of HYVs adapted to the rainfed and marginal areas.
(iv) Develop, test, and release technologies that will pose minimal or no risks to human health and the environment.
(v) Strengthen the extension, delivery, and regulatory systems to ensure that improved varieties and technologies will be disseminated widely to small farmers with little or no risk to consumers or the farmers themselves.

2. Role of Government

To use agricultural biotechnology safely and effectively for the benefit of small farmers in Asia, governments in the region should:

(i) Demonstrate a strong commitment to agriculture and rural development by providing adequate budget and staffing to the sector in general and agricultural biotechnology in particular.
(ii) Establish clear polices and priorities in biotechnology R&D to ensure that it can contribute effectively and safely toward poverty reduction and food security.
(iii) Enhance cooperation with the private sector in the development of biotechnology that will benefit small farmers.
(iv) Set up effective biosafety regulatory and enforcement systems to ensure that the risks of biotechnology (particularly those of genetically modified crops and livestock) will be minimized.
(v) Enact IPR laws that will protect and stimulate private sector investments in biotechnology in the region.
(vi) Organize dialogue with nongovernmental organizations, consumers, and farmers on the benefits, risks, and opportunities in the use of new biotechnology.
(vii) Seek assistance from international organizations and funding agencies on specific problems in biotechnology that cannot be addressed using their own resources.

3. Suggested Policy for ADB on Agricultural Biotechnology

(i) Assist DMCs in policy and priority setting to enhance investments in the safe applications of biotechnology.

(ii) Increase dialogue with its DMCs in identifying potential benefits and opportunities in the use of different biotechnologies to address specific targets.

(iii) Strengthen risk assessment and management capabilities in its DMCs through systematic capacity building.

(iv) Facilitate access to proprietary technologies and encourage greater private and public sector cooperation in the development and delivery of new products at affordable prices for the poor.

(v) Support a strategic R&D agenda and associated human resources development in Asia to generate new knowledge and disseminate the results for the public good. It should support and fund national governments and IARCs to undertake important initiatives that will have significant impact on poverty reduction and food security in the long term in areas of market failure where the private sector is unlikely to invest.