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Rice Biotechnology: Opportunity, Perceived Risks and Potential Benefits to Bangladesh

Paper 37

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The present paper **Rice Biotechnology: Opportunity, Perceived Risks and Potential benefits to Bangladesh**, has been prepared as part of CPD's on-going agricultural policy research and advocacy activities with the International Rice Research Institute (IRRI) under the Poverty Elimination Through Rice Research Assistance (PETRRA) project.

The present paper titled ***Rice Biotechnology:Opportunity, Perceived Risks and Potential*** **benefits to Bangladesh** has been jointly prepared by Mahabub Hossain **and** S.K Datta, Social Sciences Division, and Plant Breeding, Genetics & Biochemistry Division, International Rice Research Institute, Metro Manila, Philippines, Muazzam Husain , Research & Evaluation Division, Bangladesh Rural Advancement Committee, Dhaka, Bangladesh. The paper was presented at the dialogue on ***Sustaining Agriculture Growth in Bangladesh: Should We Go for Biotechnology for Rice Improvement?*** This dialogue was held on September 08, 2003 at BRAC Center INN Auditorium, Dhaka.

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Rice Biotechnology: Opportunity, Perceived Risks and Potential Benefits to Bangladesh

1. Introduction

Scientific revolution in molecular biology over the last two decades has led to rapid progress in understanding the genetic basis of living organism, and the ability to develop processes and products useful to food security, nutrition and human health. In agriculture, there is increasing use of biotechnology for genetic mapping and marker-assisted selection (MAS) to aid more precise, time-saving and cost-effective development of new strains of improved crops, animal and aquatic species. This development is encouraging particularly for developing countries since conventional breeding that has contributed to the green revolution, provides limited opportunity for further breakthrough in shifting the yield potential, solving the complex problems of insect and disease pressure, and tolerance to climatic stresses such as drought, submergence, heat and cold. Particularly appealing feature of biotechnology is the opportunity of addressing the health problems through improved crops and other agricultural products (ADB 2000; Persley, 2000).

The development of agricultural biotechnology is perceived by many as posing considerable risks to human health and environment. The current debate is focused on the initial applications of such biotechnology in developed countries where food safety rather than food security is a major concern. At present there is little commercial utilization of results from modern biotechnology research in developing countries, except for cotton and maize (James 2002). As a result, the potential contribution of biotechnology to enhanced food and nutrition security and poverty alleviation in developing countries have received little attention, beyond blanket statements of support or opposition.

A debate based on the best available empirical evidence relevant for poor people in developing countries is needed to identify most appropriate ways that molecular biology-based research might contribute to achieving and sustaining food and nutrition security. These problems and the context in which they occur are different from those in the developed countries where the debate is taking place, and hence the positions and conclusions may be largely irrelevant in the context of a particular developing country. About 1.2 billion people mostly in South Asia and Sub-Saharan Africa, live in a state of absolute poverty with an income of less than one US dollar per day (World Bank, 2000).

About 800 million people are food insecure (FAO 1999), and 160 million preschool children suffer from energy protein mal-nutrition which results in the death of over five million children under the age of five every year. A much larger number of people suffer from deficiencies of micro-nutrients such as iron and vitamin A. Food insecurity and mal- and under-nutrition result in serious public health problems and lost human potential in many developing countries. In contrast, in most developed countries the population has reached a stationary state, and in many the absolute decline in population is a cause for concern. Increased food production is no longer an issue. The developed country consumers have enough income to afford a diversified diet needed for balanced nutrition. They are more concerned with safe and healthy food and hence with the perceived risks of genetically modified organisms (GMO). The trade-off between the benefits and risks would be different between the developed and the developing world. The public policy regarding biotechnology and GMOs must take into account the individual country context rather than being influenced by the debate in the developed world.

The purpose of this presentation is to bring the debate to the context of Bangladesh. Since rice is the dominant staple food and the major source of energy, protein and micro-nutrients, we shall confine our discussion to benefits and risks of rice biotechnology research and genetically engineered (GE) varieties developed from such research. Section II explains the biotechnology tools and the rice biotechnology products in the pipeline. Section III assesses the potential benefits of biotechnology in the Bangladesh contexts. The perceived risks of biotechnology raised in the current debate are outlined in section IV. Section V presents findings of a survey on knowledge, perceptions and attitude of civil society in Bangladesh to identify the constraints to adoption of rice biotechnology in Bangladesh. The final section raises some issues for debate across the table that may assist the government to take up positions on this issue vital to achieving and sustaining food and nutrition security in Bangladesh.

2. Rice Biotechnology: Opportunities

Biotechnology tools

Rice has the smallest genome of all cereals, and is the first agriculturally relevant crop species that has been sequenced by public research institutions (Kennedy 2002). The following are some downstream approaches based on this research that will be used to incorporate and improve useful traits in the rice plant.

Functional genomics. As the rice genome is sequenced, gene discovery and assignment of gene function would be the prime target of functional genomics research. Biotechnologists are now systematically assessing the phenotypes resulting from the disruption of putative gene sequences with genetic resources such as mutants, near-isogenic lines, permanent mapping populations, and elite and conserved germplasm. To a large extent, functional genomics is analogous to the extensive germplasm screening that has allowed conventional breeding programs to extract useful traits. A large collection of chemical and irradiation-induced mutants are also being produced for forward and reverse genetics that can be used in extensive phenotype screening. These materials are at different stages of development and are available as public goods. With these genetic resources, research on functional genomics can help evaluate agronomic characters to produce a rich phenotype bank with direct links to sequence information, which will facilitate plant breeding.

Genetic engineering. This involves cloning and incorporating single or multiple genes through transformation to modify the rice plant. Protocols for rice transformation have been developed that transfer foreign genes from diverse biological systems into rice. Direct DNA transfer methods, such as protoplasts (Datta et al., 1990), biolistic (Christou et al., 1991), and Agrobacterium-mediated (Hiei et al., 1994), are routinely used to transform rice at biotechnology laboratories in the International Rice Research Institute (IRRI) and other advanced institutions in Japan, South Korea, China and India. Traditionally, the introduced genes are selected using an antibiotic selection marker. New options, however, use non-antibiotic selection methods (Datta et al, 2003) or evict the antibiotic selection marker (Tu et al, 2003). These new approaches, if successful, will remove major concerns about food safety associated with transgenic plants. Several agronomically important genes have now been successfully transferred and showed functioning in rice **(Table 1).**

Marker-assisted breeding (MAS). This involves the use of molecular markers to track traits of interest and to effectively combine multiple genes. Molecular markers have made it possible to map and tag quantitative trait loci (QTL) that affect characters such as yield, quality and tolerance to climatic and soil related stresses. Traditional breeding and backcrossing require extensive phenotypic selection; MAS is faster, more accurate, and more efficient in backcrossing populations, which can be screened at early seedling stages and under various environmental conditions. MAS is a time saving and accurate method to pyramid genes in a variety. The pyramided line usually has more durable resistance than the one with a single gene, and the former can be used as a donor for transferring resistance genes into other desirable cultivars. Unlike approaches that involve genetic modification through transformation, MAS has been considered an uncontroversial and 'benign' biotechnology. MAS is now widely practiced in Asian laboratories, in many cases it is well integrated into the rice-breeding program. The effectiveness of MAS depends upon how accurately a marker predicts the contribution of a gene to a desirable trait. In the case of many quantitative traits, the effectiveness of MAS is yet to be proven.

Areas of Application

Tolerance to abiotic stresses. The inheritance of adaptability traits, such as drought, submergence, elongation ability and tolerance for mineral stresses, is not yet adequately understood. Very little information is available on the rice plant's tolerance mechanisms for these traits. Functional genomics can generate this information for plant breeders, and both gene mapping and MAS can aid efforts to develop high-yielding rices with tolerance to these stresses (many traditional cultivars have acquired these traits through centuries of evolution, but they have very low yields). These traits are governed by a collection of minor genes. Although mapping studies of minor genes or QTL are more difficult than those of major genes, over the long-term MAS could be a more effective strategy given plant breeders's lack of success in addressing these problems. IRRI has already developed several salinity tolerant rice lines through anther culture, which could be further improved through transformation.

The focus at IRRI and NARSs are on developing germplasm (contrasting cultivars, segregating populations, near isogenic introgression lines and mutants) to which the genomic and proteomic tools are being applied under both controlled and field conditions. The outputs of the research include:

- new cultivars with stress tolerance enhanced by the combination of diverse mechanisms and the combination of tolerances to multiple stresses,
- isolated genes suitable for use in transformation, and
- transgenic rice with novel stress tolerance mechanisms derived from other organisms.

Durable host plant resistance. Host plant resistance is the cornerstone of effective pest management. Combining varietal resistance with biological agents and cultural practices can reduce the use of harmful agro-chemicals. Biotechnology tools enable the characterization of insects and pathogen population structures that can guide the deployment of pest-resistant cultivars. Over the years, many rice varieties have been developed with multiple resistance to insects and diseases. But resistant varieties do not remain resistant forever; pathogen populations adapt and break resistance. For major pest problems, it would be worthwhile to devise -a resistance mechanism using cloned genes from other sources. For rice, brown plant hopper (BPH), yellow stem borer, sheath blight and bacterial blight are targets for this approach. DNA recombinant methods are currently being used to transfer *Bacillus thuringiensis (Bt)* and chitinase genes to enhance resistance (Datta et al. 2000, 2002; Alam et al. 1998, 1999; Baisakh et al, 2000; Tu et al., 2000a,b).

Enhancing nutritional quality. The vast majority of the rural and urban poor in Asia rely heavily on rice for their major source of energy and protein. The average annual per capita intake of rice varies from 100 to 170 kilograms in most low-income countries. Consumers at low-income levels cannot afford to diversify their diets and improve their nutritional intake. As a result, micronutrient-induced malnutrition is widely prevalent in Asia. Vitamin A deficiency affects some 400 million people worldwide, leaving them vulnerable to infections and blindness. Iron deficiency affects 3.7 billion people, particularly women, leading to high maternal deaths and infant mortality. Developing micronutrient dense rices, with higher amounts of iron, zinc and vitamin A, can have tremendous impact on the health of low-income people (Underwood, 1999). Conventional breeding when combined with biotechnology can provide very powerful tools to achieve this goal (Datta and Bouis 2002).

Apomixis for hybrid seeds. Rice hybrids have been developed for both temperate and tropical agro-ecoregions that provide 15-20 percent yield advantages over inbred rices. Their adoption by farmers, however, is constrained by the need to purchase seed every season with high seed costs. Apomixis is a method of reproducing seed directly from the ovule without fertilization by pollen. Apomictic hybrid rice could be reproduced by farmers themselves at minimal cost. Studies indicate that the switch from sexual reproduction to apomixis may be controlled by as few as 1-2 genes. Biotechnology could help map and isolate the apomixis genes and transfer them to rice.

To conclude, many biotechnology applications are environmentally focused, impact oriented and complementary to conventional breeding (Hossain et al 2000). Given the private sectors huge investment in biotechnology in developed countries, researchers in public sector institutions are now wisely choosing target traits and environments that can substantially impact low-income farmers and consumers.

Achievements

In the initial years, rice biotechnology research was located in the laboratories of developed countries outside Asia (Hossain et al. 2000). The focus of the research was mainly upstream, on developing protocols and promoters for gene transformation and on gene mapping and characterization. In most cases, research was done in collaboration with graduate students from Asia. The developed countries' relative contribution to biotechnology research, however, has declined over time.

The big multinational companies who invested heavily in upstream research on biotechnology initially has back tracked in recent year. They assess that rice biotechnology research for Asia is no longer economically profitable because of the predominance of small and marginal farmers and the high transaction costs of enforcing intellectual property rights under weak judicial systems.

Within Asia, most of the biotechnology research are confined in the public sector laboratories in Japan, South Korea, India and China, Philippines and the International Rice Research Institutes. In China and India the major focus of research has remained on developing resistance to insects and diseases, on mapping QTL for yield advancements, and on exploiting heterosis for hybrids. Work on abiotic stresses, however, has remained limited. Because public sector institutions conduct most of the work, the problem of disseminating biotechnology products to low-income farmers, a concern raised by many non-governmental organizations (NGOs), may not be an issue for rice.

In Japan and Korea, per capita rice consumption has been declining, and they now face the problem of disposing of surplus rice. Still, their investment in rice biotechnology is significant and has been growing fast. Research has been conducted primarily in public sector institutions. They use biotechnology to stabilize rice yields and reduce dependence on agrochemicals such as insecticides, fungicides and herbicides. These institutions may share their biotechnology products with less developed rice-growing countries of Asia that cannot afford heavy investments for upstream biotechnology research.

IRRI accounts for only a small share of the Asian biotechnology research, but it plays a catalytic role in promoting downstream biotechnology research in Asia's developing countries by mobilizing financial support and providing training to NARS scientists through the Asian Rice Biotechnology Network (ARBN).

Asia's biotechnology research infrastructure is limited outside the countries mentioned above. But most other countries are not expected to have the resources needed to participate in the biotechnology revolution. Whether biotechnology will benefit their farmers and consumers depends on the international transfer of appropriate technologies. Such technology transfer will not be possible unless they enact bio safety regulations and put in place a regulatory mechanism for adaptive research and release of biotech products.

Some selected achievements of biotech research in developing transgenic rices through incorporating genes of agronomic value may be reviewed in Table 1. Progress has been made in herbicide tolerance and insect and disease resistance. This will benefit farmers in irrigated ecosystems by stabilizing yields at high levels and increasing profits due to reduced yield losses and lower application of pesticides. Some progress has also been made in developing submergence tolerance and in incorporating iron and vitamin A. These traits have been transformed mostly in Japonica varieties, which are grown in temperate zones in East Asia. Scientists from IRRI and selected NARS are now working for transferring these genes in popularly grown indica varieties (Datta 2000). Major products which are available but undergoing tests on biosafety and health effects are Bt rice for stem borer and sheath blight resistance, and iron- and vitamin A enriched rice.

Table1: **Selected studies to illustrate progress in rice transformation and product development**

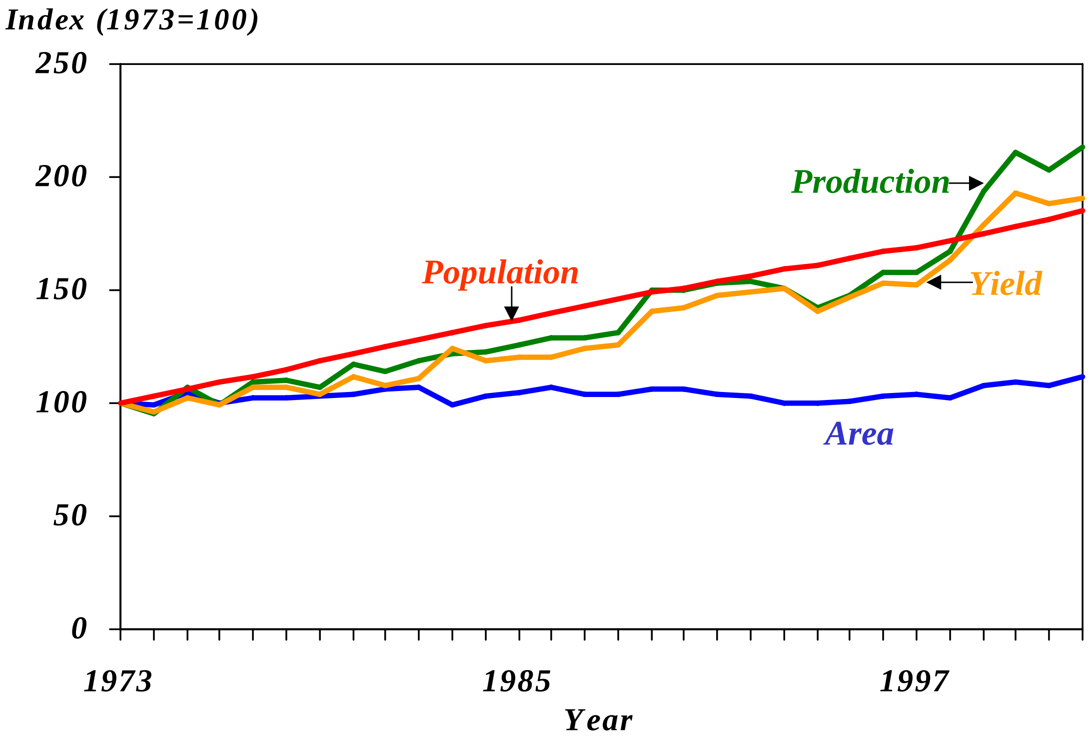
Rice variety	Method used	Gene transferred	Trait/Development	Reference
Indica	Protoplast	*hph*	Protoplast transformation	Datta et al, 1990
lndica/Japonica	Biolistic	*barlgus*	Biolistic transformation	Christou et al., 1991
Japonica	Agrobacterium	*hph/gus*	Agrobacterium transformation	Hiei et al, 1994
IR 72	Protoplast (PEG)	*bar*	Herbicide tolerance	Datta et al., 1992
Japonica	Protoplast	*CP-stripe virus*	Stripe virus resistance	Hayakawa et al., 1992
Indica	Protoplast (PEG)	*chitinase*	Sheath blight resistance	Lin et al., 1995 Datta, K. et al. 2000
Japonic	Biolistic/protoplast	*pinll*	Insect resistance	Duan et al., 1996
Indica	Biolistic/protoplast	*Bt*	Stem borer resistance (deep water/B line rice)	Datta et al., 1996 Alam et al., 1998, 1999
Japonica	Biolistic	HVAI	Osmoprotectant	Xu et al., 1996
Indica/Japonica	Biolistic/protoplast	*adhlpdc*	Submergence tolerance	Quimio et al., 1999
Indica	Biolistic	fusion *Bt*	Stem borer multiple Resistance, field evaluated	Tu et al., 2000a
Indica/Japonica	Biolistic/protoplast	fusion *Bt*	Stem borer resistance, tissue specific	Datta et al., 1998
Indica	Biolistic	*Xa-21*	BLB resistance, field evaluated	Tu et al., 2000b
Japonica	Agrobacterium	erritin	Iron improvement	Goto et al., 1999
Japonica	Agrobacterium	*psy, crtl,* lyc	ProvitaminA	Ye et al., 2000
Japonica	Agrobacterium	YK1	Blast and environmental stress tolerance	Uchimiya, et al , 2000
Indica	Biolistic	DREB	Drought/salinity	Datta 2002
Indica	Biolistic	*Xa-21* fusion *Bt*, *RC7*	BLB, stem borer & sheath blight resistance	Datta, et al 2002
Indica	Agrobacterium	TPS	Drought and salinity	Garg, et al, 2002
Japonica	Agrobacterium	GA20 ox-2	Dwarfing (green revolution)	Ashikari et al., 2002
Indica	Biolistic	*psy, crt1, lyc*	Provitamin A	Datta et al, 2003
Indica	Biolistic	ferritin	Iron enhancement	Vasconcelos et al, 2003

3. Potential Benefits: The Bangladesh Context

Bangladesh is one of the most land scarce countries in the world with cultivation frontier closed almost fifty years ago. At independence in 1971, many expressed concern about the capacity of the nation to feed its growing population. Yet the production of cereal grains in Bangladesh has more than doubled since then, despite a decline in arable land. The production of paddy rice has increased from 17.7 to 37.7 million tons and that of wheat from 0.1 to 1.8 million tons during 1970-2003. Without this impressive growth in the production of staple grains, poverty and food insecurity would have been much worse than what we observe today. The growth has contributed to an increase in food availability, kept food grain prices low and stable, and has been the major factor behind the recent downward trend in inflation, and reduction in poverty by almost one percent a year (Zohir et al. 2002).

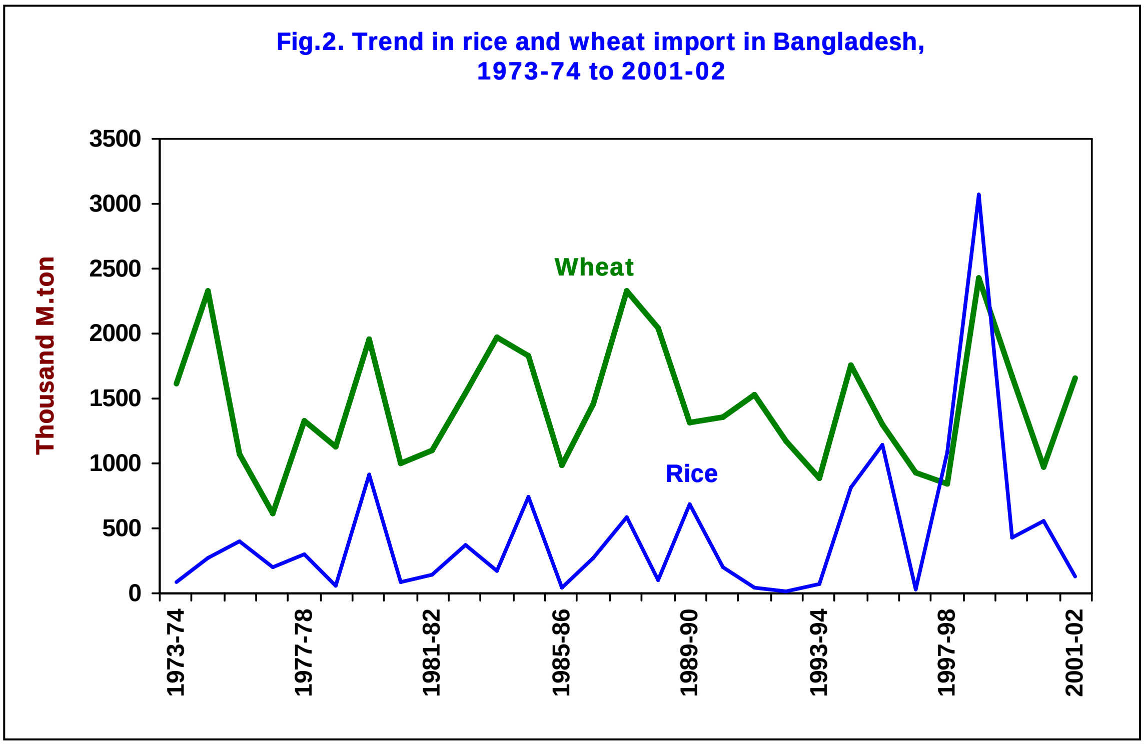
Most of the additional grain production has come from the Green Revolution – from diffusion of improved rice and wheat varieties developed by the Bangladesh agricultural research institutions in collaboration with International research centers. The modern rice variety seeds have now spread to two-thirds of the rice cropped area, supported by an expansion of irrigation facilities to over 55 percent of the cultivated area. As a result the rice yield increased from 1.7 t/ha in 1968 when the modern varieties were first cultivated to about 3.5 t/ha in 2002-03. The yield growth was almost at par with the growth of population, and the increase in production came with little increase in cropped area (**Fig. 1)**.

Fig.1. Trends in Bangladesh population, rice area, production and yield, 1973-2002.



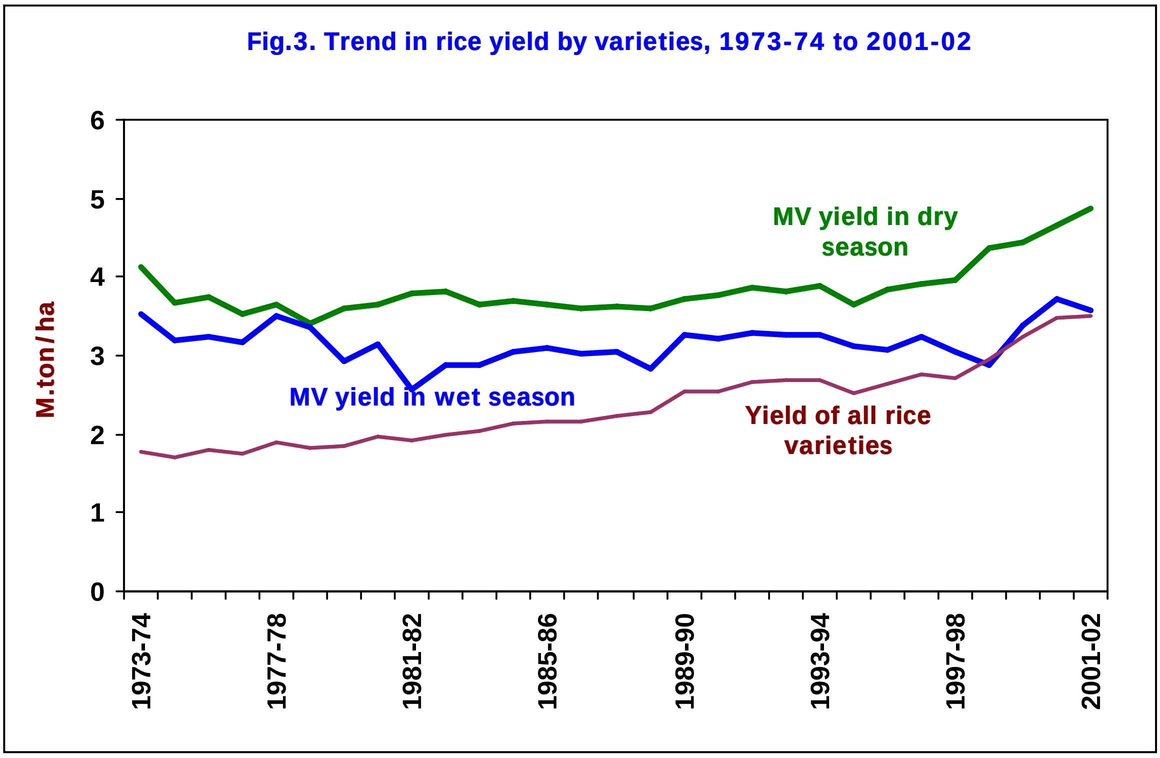
But the policy makers in Bangladesh must not be complacent with the past progress in meeting the food needs of the people. Food security will remain a major concern so long as population continues to increase. Bangladesh has also made commendable progress in reducing the population growth from 2.2 to 1.5 percent per year with the 1990s. But the country in still adding two million people every year, putting a pressure on the increase in paddy production at 0.56 million tons every year, to maintain the same level of per capita consumption. Although the government had claimed self-sufficiency in food grain production several times in the past, Bangladesh slipped back into import dependence within a few years of such declarations, as the government became complacent with the achievements and shifted its priority from food grain production (**Fig. 2**).

Fig.2. Trend in rice and wheat import in Bangladesh, 1973-74 to 2001-02



Indeed, Bangladesh must target a higher rate of growth in yield in food grain production than the required increase in demand in order to release land to other crops whose demand has been growing faster.

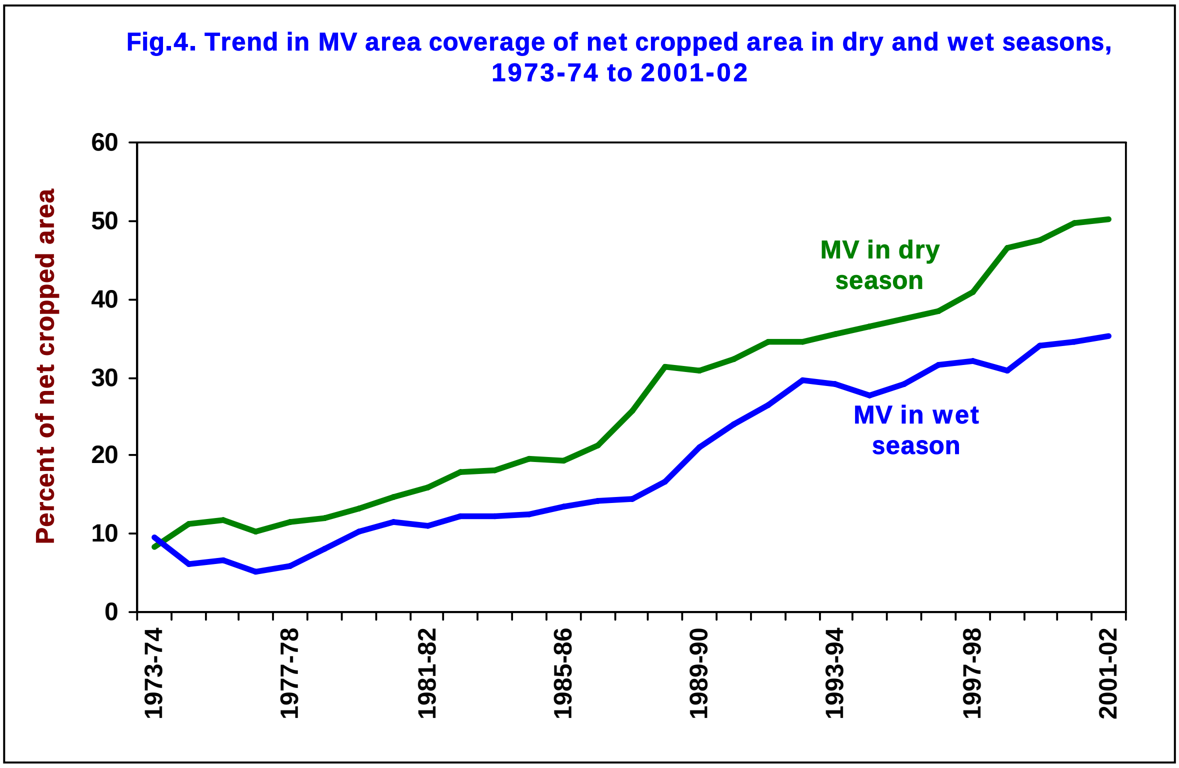
Fig. 3. Trend in rice yield by varieties, 1973-74 to 2001-02



The easy options for increasing the rice yield have already been exploited. The dominant source of increase in yields so far has been the reallocation of rice land from the low-yielding traditional varieties to the high yielding modern varieties. The level of yield for the modern varieties has remained almost stagnant till the late 1990s for both the wet (aman) and the dry (boro) seasons (**Fig. 3**). Only in the last few years the yield for boro has increased somewhat due to a) the release of two higher yielding varieties for the dry seasons-BRRI dhan 28 and BRRI dhan 29, and b) adoption of improved crop management practices, such as transplanting of young seedlings, reducing the number of seedlings per hills and wider spacing between hills. The yield is about a ton lower for the wet season compared to that for the dry season due to lower sunshine (heavy cloud cover), submergence stresses during the vegetative stage, and drought stresses during the gain filling stage. Scientists have not been successful in developing a higher yielding variety for the aman season than those released during the initial years of the Green Revolution. BR11 introduced to farmers in 1981 has remained popular in spite of a large number of varieties released for the season since then. Attempts to increase in yield through development and import of hybrid rice varieties have had limited success (Hossain et al, 2003).

The coverage of modern rice varieties have expanded to over three-fourths of the cultivated land in the dry season and one-half in the wet season (**Fig. 4**). Further expansion of area for the dry season may not be feasible and desirable due to the over-exploitation of ground water for irrigation of boro rice, and the need for crop diversification in the dry season when the agro-climatic situation is suitable for raising various non-rice crops. Rice is the only crop that can be grown during the wet season when most of the field remains submerged with water. But over 40 percent of the land in Bangladesh remain flooded at a depth of more than 50 cm where the semi-dwarf modern varieties cannot be grown. Bangladesh also has a large coastal area subjected to tidal fluctuations causing frequent submergence and mild to medium salinity for which appropriate modern varieties have yet to be developed.

Fig. 4. Trend in MV area coverage of net cropped area in dry and wet seasons, 1973-74 to 2001-02



Thus, Bangladesh must exploit all scientific opportunity for shifting the yield frontier and reducing the yield gaps for sustaining the growth in rice production. Application of modern biotechnology tools provides Bangladesh such an opportunity. As mentioned earlier, molecular markers have made it possible to map and tag quantitative trace loci (QTL) that affect characters such as yield, quality and tolerance to submergence and drought stresses. The gene for submergence tolerance (sub 1) has already been identified, which if incorporated into the popularly grown modern varieties such as BR11 and Swarna (Indian variety grown widely in the border belt) can help increase the yield and reduce the cost of production on account of re-transplanting in the wet season. IRRI Scientists have been collaborating with Dhaka University for developing high-yielding salt tolerant varieties applying biotechnology tools, which if successful can help expand area under modern varieties in the coastal region. The Bt rice has been proved effective in controlling stem borers, and chitinase genes for sheath blight disease and is now being considered for release in China and being field tested in India. Resistance against these pests has been found difficult to incorporate in high yielding varieties through conventional breeding. If the Bt rice is widely adopted farmers will be able to save substantial yield losses and at the same time reduce pesticides use that will have a positive effect on human health and the environment.

Even more important for Bangladesh is the potential benefit of genetically engineered rice in addressing major health issues. The level of micro-nutrient induced malnutrition in Bangladesh remains one of the highest in the world (ADB, 2001). Nearly 60 percent of the children under age five are underweight and more than half are stunted. Almost half of the children suffer from chronic energy deficit and more than 70 percent of pregnant women suffer from anemia due to iron deficiency. In rural areas where three-fourths of the population live, malnutrition is high due to lack of knowledge regarding (or financial capacity to afford) balanced diet or economic capacity to purchase supplemental iron and vitamin A. Since the poor consume nearly 150 to 170 kg of rice per year, incorporation of a small amount of iron and Vitamin A in rice can go a long way in meeting the deficiency of these critical micro-nutrients. Rice scientists have already incorporated iron in rice varieties using genetic engineering (Goto et al, 1999; Vasconcelos et al, 2003), which will be evaluated for bioavailability and food safety concerns. Genes controlling Beta-carotene (obtained from daffodil and bacteria) have already been incorporated into IR64, the most widely grown rice variety in the world and also in Brridhan29, the most widely grown boro rice variety in Bangladesh (Datta et al, 2003). Adoption of these varieties in Bangladesh after proper evaluation of the food safety and environmental effects and economic viability may contribute substantially to improved nutrition and human health.

4. Perceived Risks of Biotechnology

As with any science and technology, biotechnology can bring in both benefits and risks. It is the risks of agricultural biotechnology that have received widespread publicity in the media even, though there is little controversy on the application of biotechnology is widely applied to health and industrial uses. Many non-governmental NGOs are particularly vocal about the effect of genetic modification of crops on environment and human health. In the public debate, the biotechnology has become synonymous with genetically modified organisms (GMOs), although they are only one of the many products of biotechnology.

The risks associated with modern biotechnology fall into four categories: food safety, environmental safety, ethical issues and socioeconomic impact. Some of these concerns relate to potential risk inherent in any innovations and can be described as “technology inherent” (Leisinger 2000). Others are related more to value systems or cultural practices and can be described as “technology transcending”.

Food Safety Concerns

The potential risks of biotechnology on human health may include toxic reactions, food allergies, food contamination and antibiotic resistance. In 1996, a Brazil nut gene sliced into soybean was reported to induce potentially fatal allergies in people sensitive to Brazil nuts. The safety assessment confirmed that the protein was an allergen and the development was abandoned. In1998, a scientist in Rowett Institute found that genetically engineered potatoes sliced with DNA from the snowdrop plant are poisonous to mammals. The UK government’s Advisory Committee for Novel Food and Process examined the data and concluded that the experiment was faulty and the conclusions were unwarranted. In 2000, StarLink, a genetically engineered maize variety approved for animal feed (but not for human consumption), was found in an ingredient used by some US bear makers and in taco shells. The incident was caused by an accidental mix of StarLink with vast amounts of other maize during harvest, storage and distribution. The contaminated food was recalled and destroyed. Use of an anti-biotic marker gene in the development genetically engineered crops may contribute to adverse health effects of anti-biotic resistance. There is little or no evidence about this risk yet, but it has remained an emotive issue. Biotechnologists involved with transformation of genes have now replaced the anti-biotic marker with a safer marker.

To address food safety concerns many governments have established regulatory procedures, and have put in place infrastructure and institutions to implement proper safe guards. The regulations cover all aspects of the food chain, from farm inputs to production and processing, to transportation, storage and distribution. Formal science-based procedures for risk analysis of transformed food have been adopted in many countries. These continue to evolve with new scientific information on food safety. Generally, the procedures conform to international standards set by the Codex Alimentarious Commission of FAO.

Environmental Concerns

Some biotechnology applications such as traditional tissue culture or MAS breeding are not seen to present any new threats to the environments. But there is fear of potential risks from the release of transgenic varieties into the environment. These may include increased pesticides residues, genetic pollution, damage to beneficial insects, creation of super weeds and super pests, creation of new viruses and bacteria, and genetic bio-invasion. Wind, rain, birds and bees have carried genetically altered pollen into adjoining fields, contaminating the DNA or organic or non-genetically engineered crops. Pollen contamination has taken place for centuries with or without genetic engineering. The risk is however low for self-pollinated crops such as rice. Genetically engineered crops resistant to herbicides may transfer their resistance to weeds, turning them into super weeds that cannot be controlled by herbicides. Similarly resistance may be transferred to pests turning them into super pests. Scientists are monitoring the transfer of modified crops' resistance to weeds and insects. But this fear is yet to be proven. Scientists from Cornell University found that pollen from Bt maize was poisonous for monarch butterflies and later found that those data were scientifically incorrect to draw such conclusions.

Most biotechnology applications in tissue culture, and micropropagation are subject to existing regulations. They include phytosanitary regulations and plant quarantine, varietal certification of seeds, and veterinary product regulations. These regulations usually conform to international standards and guidelines. A number of countries have introduced new requirements and procedures for release of GMOs, to address the environmental concerns.

Ethical Concerns

Ethical issues may stem from individual values and national social, economic or political contexts. One of the ethical concerns raised by biotechnology, particularly genetic transformation, is that it is unnatural and unwarranted tampering of forces of nature. Indeed it may be difficult to reconcile personal values with what a majority regard as the common good. Seen in historical perspective, most technology developments in agriculture over the centuries have involved in one way or another, efforts to overcome the vagaries of nature. The conventional plant breeding that triggered the green revolution also involved tampering of nature.

Socioeconomic Risks

Unless developing countries have policies in place to ensure that small farmers have access to delivery systems, extension services, markets and infrastructure, there is considerable risk that the introduction of agricultural biotechnology could lead to increased inequality in income and wealth. In such a case larger farmers are likely to capture most of the benefits through early adoption of the technology, expanded production and reduced unit cost. Growing concentration among companies engaged in agricultural biotechnology research may lead to reduced competition, monopoly profits, and extraction of special favors from governments. Effective anti-trust legislations are absent and their enforcement is weak particularly in small developing countries where only a few seed companies operate. Under these circumstances, public sector institutions should be supported for biotech research, rather than depending on the private sector companies for such research.

Risk Management

To address the potential risks of biotechnology in agriculture developing countries must establish effective *bio-safety procedures* for the development, testing and release of biotechnology. During the 1990s, a growing number of international organizations have become involved in activities related to biosafety. FAO and WHO are jointly responsible for the Codex Alimentarious Commission, which sets international standards for food safety. Codex has set up a new International Task Force on Foods Derived from Biotechnology to develop general principles for risk analysis and to provide guidance on risk assessment. In January 2000, the legally binding Cartagena Protocal on Biosafety was adopted. This protocol lays the foundation for a global system for assessing the impact on GMOs on biodiversity. It outlines the obligations of all countries that are signatories to protect biological diversity for saving consumers from the potential risks imposed by modified living organism resulting from modern biotechnology.

Although many Asian countries have started having regulations in place, weak law enforcement might result in the release of GMOs without proper procedures having been followed. Biosafety regulations must be enacted and the infrastructure for enforcement of biosafety rules must be strengthened to minimize the risk of biotechnology products to human and environmental health.

5. Perceptions and Attitude of Bangladesh Civil Society

Given the debate on the perceived risks and benefit of biotechnology in the developed countries, it is useful to study the exposure of the Bangladesh civil society groups to the debate on and the attitude and perceptions regarding rice biotechnology research in the Bangladesh context. The study is important because the civil society groups mould the public opinion and any negative opinion may stand in the way of releasing the products, however beneficial they might be to consumers.

The Bangladesh Rural Advancement Committee (BRAC) conducted a survey of knowledge, attitude and perceptions of civil society groups regarding rice biotechnology. IRRI conducted a pilot testing of the questionnaire in the third quarter of 2002 through a series of focused group interviews with scientists and researchers in the Bangladesh Rice Research Institute and the Bangladesh Institute of Development Studies, and with teachers and students of Bangladesh Agricultural University, Mymensingh and the Jahangirnagar University. The focus group interviews covered 79 respondents. In 2003, BRAC sent the pretested questionnaire by post to key personnel belonging to civil society groups that included scientists from agricultural research institutions, senior executives of NGOs and environmental advocacy associations, senior government officials and eminent professionals. The filled-in questionnaires were returned from 232 persons. The findings from the analysis of the data are presented below.

The respondents were classified into three groups; a) scientists and research leaders of agricultural research and educational institutions, who are expected to be more knowledgeable about the potential risks and benefits of biotechnology and may be its proponents, b) managers and senior executives of NGOs and environmental advocacy associations who might have been influenced by the on-going debate in the developed countries, and may be the opponents of biotechnology, and c) other civil society groups who may be least exposed to the debate and may hold a neutral position. The groups comprised 41 percent, 18 percent and 41 percent of the respondents respectively. Two-thirds of the respondents were over 40 years of age and a similar proportion hold post-graduate degrees. Nearly four-fifths of the respondents were born in villages and rural towns who should be knowledgeable about agriculture.

To test how knowledgeable the respondents are regarding improved agricultural technology the questionnaire contained a few questions on the Green Revolution, a familiar event whose impacts are still subject to controversy in many circles. All respondents have heard of “Green Revolution” with 64 percent defining it as “dramatic increase in food grain production” and another 30 percent as “increase in food production while conserving natural resources”. The positive effects of Green Revolution were reported as “Yield increase in irrigated ecosystem”, “Reducing yield losses from pests”, “Shortening crop maturity period”, “improving grain quality” and “Yield increase in rain fed systems”, in that order of importance. Major negative effects of the Green Revolution were listed as “Use of chemical fertilizers destroys the soil”, “Intensive rice farming destroys soil fertility”, and “Cultivation of a few improved varieties erodes biodiversity”, in that order of importance. These responses suggest that the respondents have the right perceptions about the positive and negative effects of green revolution. The ranking was almost the same across the three respondent groups. It is surprising to find that the NGO respondents were not overly critical of the green revolution compared to other groups in Bangladesh, in contrast to the situation in many other countries.

About 96 percent of the respondents reported that they have heard of “biotechnology” while 56 percent reported they have heard of “GMOs”, with 86 percent among them correctly defined the “GMO” as “genetically modified organism”. Only 40 percent of the respondents reported hearing the word “Frankenstein food”, the slang version of GMO used by its critiques. The major sources of information on biotechnology were newspapers (55%), magazines and literature (24%) and television/radio (17%). NGOs were a relatively minor source of information regarding biotechnology and GMOs (11%), which indicates that in Bangladesh NGOs are yet to play an important role in negative advocacy regarding biotechnology.

The perceptions regarding negative effects of biotechnology were “Adverse effects on human health” (46%), “Threats to biodiversity and ecology” (19%), “Hazardous change in the environment” (16%), “Farmers will face seed related problems” (11%), “May change human gene and behavior” (11%) and “Unethical science” (6%). Thus the food safety concern is predominant in the mind of the respondents than environmental or ethical concerns. There is also some concern regarding socioeconomic equity as expressed by the response on farmers’ access to seeds.

In response to the question, “Whether support biotech research for rice?” a third of the respondents answered positively, and nearly 60 percent answered “yes, under certain conditions”. The conditions in order of priority were “ If environment and health impact are assessed before releasing the products” (89%), “If the products provide substantial health benefits” (58%), “If the products contribute to reduction in pesticide use” (57%) and “If research is conducted under the public sectors and the products are provided free of charge to farmers” (36%). The unequivocal positive support for biotech research was less among NGO respondents (13%) and high for respondents from agricultural research and educational institutions (41%). However, the ranking for conditions for support was similar across the three groups of respondents (**Table 2).**

Table 2. Civic society and other institutional support to biotechnology research

(Per cent of total respondents)

	NGO	Agricultural Institution	Other Civic Society	All Groups
Support to biotechnology				
Will support	**13**	**41**	**32**	**32**
Will support under certain conditions below:	**82**	**52**	**64**	**62**
If research is done by public sector and the technology provided free to farmers	36	39	34	36
If environment & health impact assessed before releasing	80	96	89	89
If the technology provides substantial health benefits	49	63	60	58
If the technology help reduce use of pesticide	51	60	7	56

Only six percent of the respondents were not supportive of biotech research in Bangladesh. The opponents were almost the same proportion for the three groups. This result is surprising as we expected a much larger proportion of NGO respondents would be opposing biotech research. The reasons for opposing biotech research were stated as "Dependence of farmers on private companies" (59%), "Charging high prices of seeds by multinationals" (47%), "Biotech food will be allergenic to humans" (41%), and "Gene transformation is unethical" (35%).

In response to the question, "whether support import of transgenic rice varieties into Bangladesh?" 52 percent of the respondents answered positively and another 39 percent, under certain conditions. The positive response (including the conditional positive) was 96 percent for respondents from the agricultural research and educational institutions, and 89 percent for the NGO and other civil society groups. The major conditions for support were stated as, "If food safety and environmental impact are assessed", and "If field testing is done under biosafety regulations". A large number of responses related to social and economic benefits.

Since the respondents may not be aware of the recent developments in rice biotech products, potential benefits of the products which have already been developed in the laboratory were explained in the questionnaire, response was solicited regarding the advisability of their field testing in Bangladesh. One such product is Bt rice which is resistance to stem borer, the major insect pest in Bangladesh. This genetically engineered seed will contribute to reductions in pesticides use and will be beneficial to human health and environment. Majority of the respondents however reported that the pesticide use in rice cultivation is not a serious problem for Bangladesh.

IRRI scientists have incorporated high iron by conventional and genetic engineering into high yielding rice varieties. Twenty eight percent of the respondents agreed that iron deficiency is a very serious health problem in Bangladesh, and another 54 percent, as a serious health problem. Eighty percent of the respondents supported field testing of iron-enriched rice in Bangladesh. The support was also very high among the NGO (74%) and other Civil Society groups (78%).

IRRI scientists have also incorporated genes controlling beta-carotene into Brridhan29, the most popular boro variety in Bangladesh. These genes however come from bacteria and daffodils and have been incorporated in rice using the Agrobacterium transformation method. Hence it is a transgenic variety, and the rice would be a genetically modified food. However, since the rural and urban poor in Bangladesh consume about 170 kg or rice per year, nearly 25 percent of their Vitamin A needs will be met if this variety is consumed. Vitamin A deficiency was considered a very serious problem in Bangladesh by 31 percent of the respondents, and a serious problem by another 54 percent. Thus, a overwhelming majority considered it a major health issue for Bangladesh. Eighty two percent of the respondents supported field testing of Vitamin A enriched rice in Bangladesh.

To conclude, the Bangladesh civil society is quite aware of biotechnology and GMOs with a fairly good knowledge and understanding of the potential benefits and risks. The major sources of information are newspaper and electronic media. Only a small minority has got the information from NGOs, some of whom strongly oppose biotechnology research. A large majority supports biotech research on rice and import of GMOs, if their food safety and environmental effects are properly assessed and the field testing is done and supervised under proper bio-safety regulations. Majority are supportive of field testing of genetically engineered iron and vitamin A enriched rice in Bangladesh, as they consider iron and vitamin A deficiency serious health problems.

6. Concluding Remarks

“Modern biotechnology is not a silver bullet for achieving food security, but if used in conjunction with traditional or conventional research methods it may be a powerful tool in the fight against poverty” (Pinstrup Anderson and Cohen 2000). In Bangladesh biotechnology may help achieve productivity gains needed to feed a growing global population, introduce resistance to major pests and diseases without farmers having to apply harmful agrochemicals, reduce yield gaps by developing varieties tolerant to adverse weather and soil conditions, and improve the nutritional value of food.

Many argue that the investment requirement for biotechnology is huge and may be beyond the capacity of the governments in many low-income developing countries, such as Bangladesh. It is further argued that the private sector has the capacity and inducements to invest in biotechnology research because of the intellectual property rights (IPR) granted under the agreement on the Uruguay Round trade negotiations, so, there is less compulsion on the part of the public sector to invest in biotechnology. One must realise however that bulk of the modern biotechnology research were undertaken by private sector companies they would protect IPRs through patents that extend beyond the first release. Farmers therefore would not be able to plant, or sell for planting the seeds kept from harvest, an age-old practice in most developing countries. Although a small fraction of the benefits of the new technology is appropriated by the inventor corporations and seed companies (Falck-Zepada et al. 1999), the adoption of the new technology would be constrained if the farmer had to purchase seed every year, from the private sector.

The share of private sector in total agricultural research fund is substantial in the developed countries but only marginal in the developing countries (Leisinger, 2000). This is not unexpected in view of the perceived small market of high cost seeds in agriculture dominated by millions of small and marginal farms, and the high transaction costs of protecting IPRs in developing countries that have weak legal and judicial systems. For addressing the issues of food insecurity and poverty biotechnology research must focus on the problems of small farmers and poor consumers and on problems that the conventional plant breeding has found it difficult to address. Private sector research is unlikely to take on such a focus, given the lack of markets that ensures adequate returns to investment. Thus, there is a need to develop biotech research facilities in public sector institutions. Without a stronger public sector role a form of "scientific apartheid" may develop, in which cutting edge science becomes oriented exclusively toward developed countries serving the interests of large scale farmers (Serageldin 1999).

The government of Bangladesh must take a stand on biotechnology research and import of GMOs, and should have a proper policy in place. The Bangladesh civil society is not yet hostile to biotech research and GMOs, if regulated under international standards of biosafety. The government has already developed biosafety regulations which may need to be ratified by the Parliament. The implementation mechanism, including setting up of committees with representatives from different organizations has also to be put in place so that public and private sector research organizations can start testing the genetically engineered products in Bangladesh. The government should also be proactive in adjusting the education and research infrastructure and course curriculam, for bringing the benefits of this cutting edge agricultural science to the doorsteps of poor farmers and consumers in Bangladesh.

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