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Agricultural Biotechnology For Green Revolution–Perceived Expectations And Potential Risks

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Abstract: Biotechnology and Green Revolution are interrelated issues. The Green Revolution is attributed to Biotechnology. The Green Revolution was an effort to reduce hunger through the improvement of agricultural crops in developing countries. The revolution has been engineered through the introduction of agricultural biotechnology that ensured scientifically bred, high yielding rice, wheat, and maize varieties in developing countries during the 40's, 50's and 60's. Among the various dimensions of biotechnology, agricultural biotechnology is by degrees getting special attention of the governments of the developing nations particularly third world and fourth world with the extension of green revolution. The developments in agricultural biotechnology in these countries are so rapid that governments of such nations are stimulated to devise their national programs aimed at realizing its potential benefits. Organizations that produce and market biotech products have been able to convince the farmers that biotechnology has had a great contribution in increasing grain yields and thus revitalize green revolution. No doubt the green revolution sparked by agricultural biotechnology has served well to increase the agricultural productivity. To this view, many feel that this is the future of agriculture and there is much promise in this new technology. But others would like to wait for exaggerated claims of return to organic farming. Even many are ignorant about this technology. However, with this new technology and resulted green revolution researchers have triggered that the new technology is not the only panacea to increase grain yields and reduce hunger, some other factors still have the influence in solving the present problems. So, it studied the expectations and potential risks of the agricultural biotechnology and its contribution toward accelerating green revolution in the developing countries with regard to promised claims of the technology.

Key words: Agriculture, green revolution, biotechnology, bioproducts, organization

Introduction

The United Nations observed October 12, 1999, as the Day of Six Billion- the world population had doubled since 1960. In some parts of developing world, the population grew even faster, in Sub-Saharan Africa, for example, it tripled. The number of people in Asia grew most in absolute terms, by nearly 2 billion. Most population experts expect that world population will grow by another 50 percent-this means at least 3 billion more people by 2050. Almost all this growth will occur in less developed regions (United Nations Population Fund: 1999, Table 1). The impact of such increased population is very adverse particularly in developing countries where the agriculture is treated as the major economic activities and accounts for lion share of GDP. Prinz (1986) has explained the effect of high population pressure on agricultural production.

In the developing world today, an estimated 800 million people already don't have enough to eat, the majority was in Asia. Another 34 million people in the industrialized countries and countries in transition also suffer from chronic food insecurity (UN FAO, 1999). Every minute, some 30 people die of hunger in the developing world and half of these are infants and children (World Bank, 1999). More than 5000,000 children go blind each year from a lack of vitamin A, iron, and other nutrients contained in plants. Another problem in developing countries is widespread zinc and iron deficiency. Between 40-50% of children under the age of five are iron deficient. This deficiency hits pregnant women even harder, accounting for 20% of all maternal deaths. The occurrence of zinc deficiency is unknown, but is probably a problem wherever hunger occurs. Scientists have added a gene to rice from a French bean that doubles the iron content of rice (Sam Behrens *et al.,* 2000). World Bank President James D. Wolfensohn says in October 1999, "if the world cannot make progress against hunger and poverty, by year 2025, there could be 4 billion people living on less than US$2 per day and more than 2 billion living in extreme poverty. To tackle this enormous challenge, the international community must launch a new Green Revolution, more powerful and encompassing than the one that 30 years ago that doubled production of key crops such as Rice and Wheat (World Bank, 1999). And food production will have to increase by more than 50 percent to feed an additional two billion people by 2025 (Mahendra Shah, 1999). In this respect, the world must either increase the cultivable land or, seek new scientific developments (like agricultural biotechnology) to radically reshape the world's

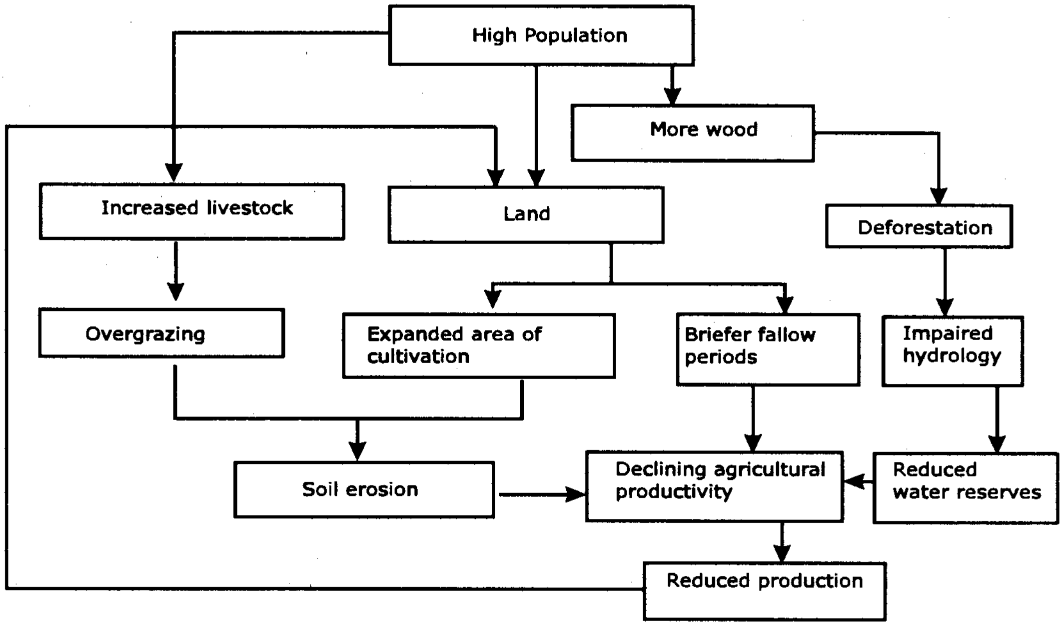

Fig.1: Effects of high population pressure on agricultural production
Source: Novartis foundation of Sustainable Development in Prinz, D.: (Available in http://www.foundation.novartis.com/population_pressure.htm).

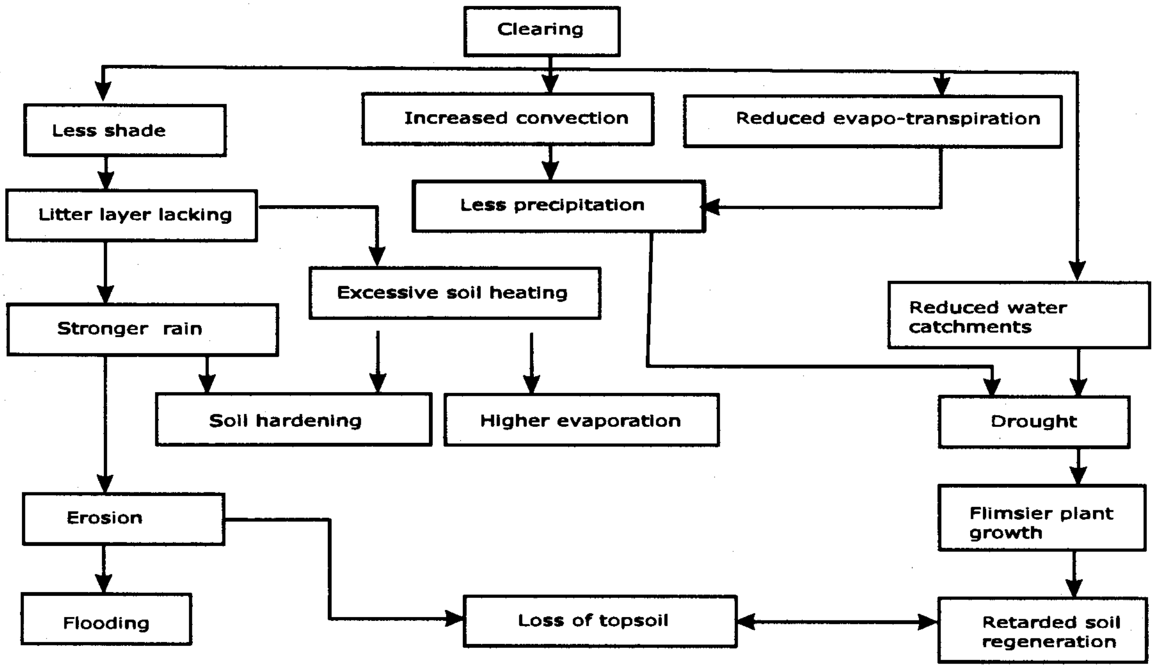

Fig.2: Effects on agricultural productivity of expanding acreage by clearing tropical forest
Source: Novartis foundation of Sustainable Development in Prinz, D. (Available at http://www.foundation.novartis.com/tropical_forest.htm)

agriculture and food system (Maurice Strong, 1999). The basic argument of those who defend the use of genetic engineering in agriculture is that food production can be increased without having to make more land available for agriculture. Even the expanding acreage by clearing tropical forest or by other ways have the negative impacts on agricultural productivity as well as cause environmental degradation. The effect of expanding cultivable land by clearing tropical forest is shown in Fig.2.

While the United States-the undisputed leader in this field, most agrarian economies are discovering and experimenting biotechnology for increasing their grain yields and reducing hunger either by importing biotechnology from developed nations (like USA, Western Europe and Japan, others are emerging) or just by very limited research initiatives. Even though the third world countries could have been blessed by this new technology and embraced green revolution by using miracle seeds, the long term effect of such technology, as the researchers opine, may somewhat be static.

In developing countries (approximately 98 countries), farmers are already sharing in the benefits of agricultural biotechnology and appear to have profited. The gains were miracle between 1990/92 and 1995/97, and onward. Table 2 shows the biotechnology programs by some developing countries.

Producers [such as Monsanto, Du Pont (pioneer) and Novartis (recently merged with AstraZeneca to form Syngenta AG)] have proven that agricultural biotechnology holds promise on many fronts including reducing hunger and malnutrition. Others think that it is not the absolute answer to solving malnutrition and hunger problem, as there are other factors such as poverty, economics and politics that have continuous impact on hunger (Sam Behrens *et al.,* 2000).

Table 1: Current and Projected Population, by Region, 2000-50 (in Million)

Region	Population		
	2000	2025	2050
World	6,070	7,909	9,243
More Developed	1,184	1,232	1,222
Less Developed thereof in	4,886	6,677	8,021
Africa	800	1,258	1,804
Asia	3,566	4,707	5,379
Latin America	520	712	838

Source: Population Reference Bureau, Washington, DC, May 2000

Although biotechnology is still controversial and the promises are yet to be delivered, it is contended that these goals can be achieved (Ruhul Kuddus, 1996). To do this, biotechnology requires the managerial and marketing skills beside strong research capabilities. A biotechnology product or service (offered by govt. and private research organizations) must be competitive to the traditional alternatives (traditional seeds not modified to ensure higher productivity) in the value and comfort (Ruhul Kuddus, 1996).

Conceptual Background: Biotechnology is defined as any technique that uses living organism (or parts thereof) to make or modify products, to improve plants and animals or to develop microorganisms for specific uses (US Congress, 1984). Operationally it combines the ideas and needs of bio-medical sciences with engineering to bring forth new products and services from living organisms or other components (Ruhul Kuddus, 1996).

Biotechnology may be both traditional biotechnology and modern biotechnology. In agriculture, the term encompasses not only well-established techniques such as those used in biological pest control and the production of vaccines and biofertilizers, but also more recently available technologies, particularly those associated with recombinant DNA (rDNA-discovered in early 70s) technology, monoclonal antibodies; and new cell and tissue cultpre techniques. For this agriculture is broadly defined as the use of the natural resources base to produce crops, livestocks, fish and trees (Komen and Persley: 2001-report). Agricultural biotechnology embodies all these attributes. Thus biotechnology is the combination of three important processes including rDNA, modern antibody production and cell & tissue culture that forms the basis of genetic engineering of microbes, plants, and animals. There are a number of research institutes in Bangladesh working with the plant genetic resources and their conservation, new cell and tissue culture, production of vaccines and poultry feeds and other genetically modified products. Table 2 shows the list of some institutes engaged in biorevolution in Bangladesh. Fifth Five Year Plan (1997/2002) of GOB also emphasised on the development of biotechnology research centres and biorevolution in Bangladesh.

To sum up, the modern biotechnology describes the integrated application of biochemistry, microbiology, and process technology with the objective of turning to technical use of potential of micro-organisms and cell and tissue cultures. The key components of modern biotechnology thus include the following (Persley and Doyle, 2000):

1. Genomics-the molecular characterisation of all species;
2. Bioinformatics-the assembly of data from genomic analysis into accessible forms ("genetic fingerprinting");
3. Tissue culture;
4. Transformation-the introduction of single genes conferring potentially useful traits into plants, livestock, fish, and tree species;
5. Molecular breeding-increased efficiency of selection for desirable traits in breeding programs using molecular marker-assisted selection; and
6. Diagnostics-the use of molecular characterisation to provide more accurate and quicker identification of pathogens

Table 2: Biotechnology programs by country

Country	Government Programs		
	Program	Prime co-ordinating Agency	R and D Base
China	Biotechnology priority in five-year Plans and long-term High Technology Development Program (1986-2000).	CNCBD	SCBD CAAS
Colombia	National program formulated	National biotechnology council COLCIENCIAS	ICA UNC Private sector
Egypt	National Institute (AGERI) No national co-ordinated program	ASRT	
India	Extensive national biotechnology program developed since 1980.	DBT	Research system under ICAR Universities Private sectors
Indonesia	Pattern of Development of Biotechnology in Indonesia Centers of excellence designated	National Committee for Biotechnology	National Centres of excellence IUCs AARD
Kenya	National Planning Conference (1989 and 1990). National program developed by NACBAA	National Council for Science and Technology.	KARI Universities
Malaysia	Priority in current national plan period. Centers of excellence designated	National Biotechnology Working Group.	MARDI PORIM, PRIM, FRIM Universities
Philippines	National institute (BIOTECH) Biotechnology Implementation Plan	Presidential task force	BIOTECH Universities
Thailand	Priority area of current national plan	NCGEB NSTDA	NCGEB's affiliated centers
Zimbabwe	Being prepared by RCZ. National Institute (BRI) being established.	RCZ	Institute under ministry of agriculture. SIRDC. University of Zimbabwe

Source: John Komen and Gabrielle Persley, ISNAR (International Service for National Agricultural Research) research report-2 in "Agricultural Biotechnology in Developing Countries- a cross country review", A biotechnology research management study by IBS (Intermediary Biotechnology Service)

The myth of the Green Revolution goes like this: the miracle seeds (A miracle seed is a combination of green seeds, chemical fertilizers, pesticides, irrigation and replacement of traditional farming practices) of the Green Revolution increase grain yields and therefore are a key to ending world hunger. The supposition can be illustrated in Fig.3. According to the supposition that the biotechnology claims, the new technology is associated with higher grain yields in developing nations (countries whose economies are mainly agrarian), the higher yields mean more income for the poor farmers, helping them to climb out of poverty and more food with less hunger. But let us see how

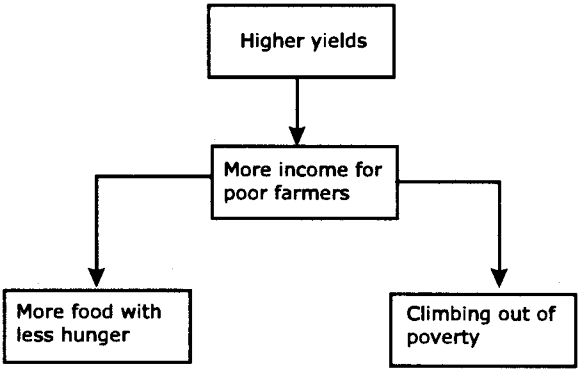

Fig.3: Increasing grain yield by green revolution

this myth really goes on. The grain yields may be increased but to what extent it carries benefits for the betterment of the rural poor and marginal farmers when the farmland is, like other commodity, bought and sold, or the society allows the unlimited accumulation of farmlands by a few super farms replacing family farms-the most common case that the developing nations are confronting with. The Green Revolution embarked with the agricultural biotechnology revolved around the introduction of scientifically bred higher yielding rice, wheat, and maize varieties in developing countries in past several decades. The movement is credited by many for helping to alleviate hunger in developing countries. In several cases, nations become food sufficient and actually become net exporters of crops.

Historical Background: Biotechnology has been in research for the past couple of decades. Both biotechnology and genetic modifying organisms (GMOs) have been used for centuries by all different kinds of human societies throughout world history. The desire to increase crop yields to meet escalating demand for food due to expanding population in the world was one of the driving forces supporting the use of chemical applications in agriculture in the past and continues today. Although modern biotechnology may have originated in 1944, when Waswald Avery and his colleagues discovered DNA as the hereditary material (Avery *et al.,* 1944) using the phenomenon of bacterial transformation originally described by Griffith in 1923. As early as 1000 BC when Chinese used sulphur as fumigant. In the 16th century, arsenic containing compounds were utilized as insecticides. It was 1700's, when hybrid plants were being used to breed and make new varieties. These new varieties helped farmers to improve crop productivity, and to become disease-resistance. Then, in the 1800's, Gregor Mendel discovered through many experiments a small-unseen particle called genes. These genes carried hereditary traits that can be passed down. In the 1900's, biotechnology became more specialized as scientists researched and experimented to find out more information. By the 1930s, the production of modern synthetic chemicals commenced (Hayes, 1993). The post war (World War-II) era marked the start of the modern agrochemical industry (Hayes, 1993). In 1950's and 1960's, two scientists discovered DNA (Deoxyribo Nucleic Acid), which directs cells to make the proteins that are the basis of life. Also scientist learned how DNA works and its development through living organisms. Agricultural biotechnology gained momentum when the term green revolution was coined in the 1960s to highlight striking breakthrough using the "miracle seeds" created by IRRI. The "miracle seeds" quickly spread to Asia, and soon new strains of rice and corn were developed as well. By the 1970s, the revolution was well deserved, for the new seeds accompanied by chemical fertilizers, pesticides, and for the most part, irrigation had replaced the traditional farming practices of millions of Third World farmers. In 1973, two university scientists transferred the first genetic material from one organism to another. By the 1980's, scientists could readily transfer genes from one organism to another to improve implant varieties. The ability to move genes provided the foundation for genetic engineering, or genetic modification, allowing the improvement of many crops through transfer of a single desired trait (Whiting). By the 1990s, almost 75 percent of Asian Rice areas were sown with these new varieties (using bio-products); the same was true for almost half of the wheat planted in Africa and more than that in Latin America and Asia, and about 70 percent of the world's corn as well. Overall, it was estimated that 40 percent of all farmers in the Third World were using Green Revolution Seeds, with the greatest use found in Asia, followed by Latin America (Peter Rosset *et al.,* 2000). Thank to the new technology, tens of millions of extra tons of grain a year are being harvested (Peter Rosset *et al.,* 2000). In 1994 the first genetically modified food was marketed in the USA. As of 1996 Bt crops were introduced in the USA, reducing the use of insecticide. And these crops consisted of corn, soybeans, and cotton. In 1998 nearly 30 million hectares of genetically modified crops were being planted in other countries but mostly the USA. These crops were being traded extensively world-wide. The area planted with transgenic crops went from 2.8 million hectares in 1996 to 12.8 million hectares in 1997.

Bio-product Producers in the World: The three top players in the biotech seed industry include Monsanto, DuPont (Pioneer) and Novartis (recently merged with AstraZeneca to form Syngenta AG). These are private companies, and have and continue to aggressively pursue these new technologies, with a primary interest of selling seeds resistant to herbicide, insecticide and other agronomic input factors. These organizations develop, produce, and market a full line of seeds, microbial products and services to grain and livestock producers, grain processors, and other customers in over 120 countries worldwide.

The renowned institution in agricultural research "The Rockefeller Foundation" encourages the adoption of biotechnology. During the 1970's, one of its staff members, Norman Borlaug, won the Nobel Peace Prize for his efforts to modernize agriculture in developing countries.

One of the most influential groups in the area of biotechnology adoption involves CGIAR (Consultative Group on International Agricultural Research)-an association of nearly 60 public and private sector members that support a network of 16 agricultural research centers. The World Bank, United Nations Development Program, and the Food and Agricultural Organizations of the United Nations are all sponsors of this organization.

Perceived Expectations and Potential Risks of Biotechnology

Expectations and Achievements: The new technology has immense benefits including disease resistance, reduced pesticide/herbicide use, more nutritious composition of food and feed grains, herbicide tolerance, more rapid growth of crops, increased yields, drought and flood tolerance, and increased taste and quality of food products (CFIA, 1997 and Anon., 1993).

Today there are about 40 varieties of genetically modified varieties of crops that account for about 60-70% of the foods on our grocery shelves (Sam *et al.,* 2000). The following table shows some GMO's and their products:

Food Commodity	Genetic Modification	Foods, Ingredients and Additives Derived form GM Food
Soybean	Herbicide Tolerance Higher unsaturated oil content	Soya beverages, tofu, soya oil, soya flour, lecithin,hydrolyzed vegetable, proteins, tocopherols
Canola	Herbicide tolerance	Edible seed products, edible oil products, tocopherols
Corn or Maize	Herbicide tolerance Insect pest resistance	Corn oil, corn meal, cornstarch, corn sugar or syrup, glucose maltodextrin
Potato	Plant virus resistance	Potato flour, potato starch, dehydrated potato flakes
Cotton	Herbicide tolerance Insect pest resistance	Cottonseed oil and linters, vegetable oil, small good casings

Source: Sam *et al.,* 2000

The acreage of transgenic plants is also increasing. The following table shows the increasing trend of GMO's planted land areas:

Millions of Acres of GMO's, by country and year

Country	1996	1997	1998
USA	3.75	20.25	51.25
Argentina	0.25	3.5	10.75
Canada	0.25	3.25	7
Australia	<0.25	0.25	0.25
Mexico	<0.25	<0.25	0.25
Spain	-----------	-----------	<0.25
France	-----------	-----------	<0.25
South Africa	-----------	-----------	<0.25
Total	4.25	27.25	69.5

Source: James (1997and 1998) in Sam *et al.*, 2000

The figure as in the table has increased more in 1999, nearly 100 million acres around the world were planted with transgenic crops (Leisinger and Klaus, 2000). As the new technology claims, by dint of it there has been a green revolution that increases grain yields and lessens world hunger. The apparent progress that the total food available per person in the world rose by 11 percent and hunger people dropped by 16 percent over two decades (between 1970 to 1990) with the rapid advances in green revolution (Peter Rosette *et al.*, 2000). Professor Mazoyer in a recent FAO publication "The State of Food and Agriculture 2000", puts "after 50 years of modernization, world agricultural production today is more than sufficient to feed 6 billion human beings adequately". Hopes continue to be high. A World Bank Panel predicts that efforts to improve rice yields in Asia through biotechnology will result in a production increase of 10-20 percent over the next 10 years (Kendall *et al.*, 1997). The new technology is also beneficial in the sense that it increases productivity. The developing world is facing decline in long term productivity of agricultural soils because of heavy degradation, huge fertilizer use, salinisation and waterlogging of irrigated land (instead rainfed agriculture-dependence on the nature most common in developing world). All these have the negative effects on agricultural production, rural food consumption, on agricultural markets and rural income. Low and declining soil fertility is a serious problem in Africa, where about 86 percent of countries show losses of nutrients greater than 30 kgs of fertilizers per hectare per year (Anderson *et al.*, 1999). Norman Borlaug's example can be quoted in this regard, "in 1999 India produced about 220 million tons of grain, within an average yield of 2.2 tons per hectare, the yield figure was 0.95 tons per hectare in 1961-63 (Leisinger and Klaus, 2000). Also when the supply of land is limited and the soil degradation is very high, the use of biotech products is a must. The arable land per person is also decreasing. In 1960 the world still had 0.44 hectares of arable land per person; today the figure is about 0.22 hectares per person, and by 2050 it is expected to drop to 0.15 hectares (World Resource Institute *et al.*, 1999). The expansion of cultivable land areas will at best contribute 20 percent to the increase of food production (mainly cereals) (Anderson *et al.*, 1999). Agricultural biotechnology is one the most important answer as to the higher yields with limited land supply.

Biotechnology research offers powerful tools for crop improvement, for example, in China, where transgenic varieties are now routinely produced in crops such as rice, corn, wheat, cotton, tomato, potato, soyabean, and rapeseed. The objectives of this research and development are that are disease-resistant, tolerate abiotic stress, and have improved product quality and increased yield potential (Zhang, 2000). China is doing spectacularly well with Bt cotton, increasing yields and reducing the number of pesticides spraying from about 12 to 3 per person (Gordon Conway, 2000). Schuler *et al.*, (1999) demonstrated that genetically modified crops designed to kill insect pests had no effect on beneficial insects.

Researchers from Washington State University were able to transfer maize into rice. Rice also can be modified so that it can contain increased level of vitamin A. GM rice unveiled in late March 2000 in Philippines at an international conference on rice biotechnology, boosts yields by a massive 35 percent. As an added benefit, the genetically modified (GM) rice, which has been tested in China, South Korea, and Chile, extracts as much as 30 percent more carbon dioxide from the atmosphere than controls, offering a way of curbing climate change (New Scientist, 2000). It will soon be possible to achieve a similar result with regard to iron. This could be of immense benefit to about 250 million poor, malnourished people who are forced to subsist on rice. The consequences of this restricted diet are well known. 180 million people are vitamin A deficient. Each year 2 million of them die, hundreds of thousands of children turn blind, and millions of women suffer form anemia, one of the main killers of women of childbearing age (WHO, 1999 and UN/IFPRI, 2000).

Thanks to the new technology. India has achieved a lot through biotechnology. The achievements include tissue culture generation, stress biology, and marker-assisted breeding as well as new types of biofertilizers and biopesticide formulations. Research to develop genetically improved (transgenic) plants for brassicas, mung bean, cotton, and potato is well advanced (Sharma, 2000). Progress adapted to local needs and priorities are under way in the Philippines, Thailand, brazil, Costa Rica, Mexico, Egypt, Iran, Jordan, Kenya, South Africa, and Zimbabwe (Persley and Lantin, 2000). Other countries including China, Colombia, Indonesia, and Malaysia have designed biotechnology programs (Table 3).

Although Bangladesh does not have any national co-ordinated program, Bangladesh Agricultural Research Council (BARC) acts as the prime co-ordinating agency for agricultural research and development. The National Agricultural Policy has emphasized on biodiversity and biotechnological development. The government (through the Science and Technology Division) conducted a feasibility study for a biotechnology research facility using a local consultative group, which submitted the final report in March 1993 and suggested to establish an institute (Institute of Applied Biotechnology or IAB). However, Bangladesh already has over fifty research institutes. Most of them are involved in a number of projects on biochemical sciences/agricultural research (Ruhul Kuddus, 1996). Table 3 indicates some of the institutes, GOs, NGOs and other private organizations work as the research organs in Bangladesh. It needs more extensive biotechnology research. As it is still struggling to climbing out of "fourth world"-the poorest of the poor (Heitzman and Worden, 1989) and the agriculture being the largest employer of the country accounting about 50 percent of its GDP, the agricultural production should be increased. So, the nation's economy will remain agrarian, a vigorous development in agricultural sector is essential and for that reason biotechnology will be helpful. The technology transfer during the Green Revolution and endogenous R&D in Agriculture has contributed to this feat (Hossain, 1991).

Potential Risks and Impact on the Developing Countries: Pure and concrete instances are there. Like other new technology, Agricultural Biotechnology is not also out of criticisms and shortcomings. This technology has some inherent risks. In Central Luzon, Philippines, rice yield increased 13 percent during the 1980s, but at the cost of a 21 percent increase in fertilizer use. In the Central Plains, yields went up only 6.5 percent, but at the cost of a 24 percent increase in fertilizer and 53 percent increase in pesticides (Peter Rosset *et al.*, 2000).

As per as social and political risks are concerned, today's criticism of genetic engineering and biotechnology is structurally similar to discussions about the Green Revolution in the 1970s (Leisinger and Klaus, 2000). The improved plant varieties that give rise to the Green Revolution of the 1950s and 1960s were developed through systematic selection and crossing (hybridization), with the objective of increasing production and averting famines, particularly in Asia. Despite undisputed success in achieving significantly higher food production and an overall positive employment effect, there was (and still is) substantial criticism of the Green Revolution as being responsible for growing disparities in poor societies and for the loss of biological diversity (Barker *et al.*, 1985).

In his treatise "Biotechnology and the Third World", Nigel Dower, professor of University of Aberdeen identified four types of issue which arise with regard to the impact of biotechnology on the third world: (1) import substitution (2) promotion of new genetically engineered seeds (or animals) which (i) creates dependency on supplying companies (ii) marginalise those who do not (iii) threaten biodiversity in agriculture which causes the impoverishment of global ecosystem, disappearance of a specific individual species and loss to local environment affecting the long-term prospects for the livelihood and development of local population in the third world (3) Northern dominance in the global economy reinforced by the patent system (4) expropriation of genetic material from the third world and then the return of it with "value" added to the Third World.

So far, for the third world, development and growth has meant, the exploitation of its resources for the benefit of their own values and traditions, their independence, the destruction of their environment, poverty and war.

Conclusion

In fact, no technology is out limitation. The same view is contained in the declaration signed by more than 1500 scientists world-wide (including several Nobel Laureates) in support of agricultural biotechnology:

No food products, whether produced with recombinant DNA techniques or with more traditional methods, are totally without risk. The risks posed by foods are a function of the biological characteristics of those foods and the specific genes that have been used, not of the processes employed in their development (Internet, 2000).

What makes a technology safe or unsafe is the way it is applied and the outcome of that application. The risk of allergy to genetically modified goods seems to be controllable and therefore minimal (Lehrar, 1999).

Agricultural biotechnology can provide the developing world with a highly effective technology to facilitate food security for a growing population. But given the complexity of socio-economic, political, and ecological problems behind deficits in food security, agricultural biotechnology cannot be a silver battle or a miracle cure for all problems in all countries. A successful battle for food security in the developing world requires battles on many different fronts-economy, social policy, gender policy, ecology, water and soil management, agronomy, breeding programs, agricultural extension, farm management, pest management and others (Leisinger and Klaus, 2000).

In fine, governments, NGOs, civil society, and the private sector organizations around the world must provide the means for mobilizing science and research for sustainable food and agriculture. In this regard, the developing countries may follow the instances of developed countries. The developed countries provide much more subsidies for their agriculture than the developing countries. The third and forth world should also provide high subsidies for agriculture and agricultural research for the food commodities of the poor. If agricultural biotechnology is used wisely in conjunction with conventional breeding, improved agricultural methods, and better agricultural policies, it can become a powerful tool in the fight for hunger problems and feed nearly 9 billion inhabitants in 2050 around the world.

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