Biotechnology, GMOs and Development: Economic Implications

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Introduction

The practice of biotechnology in its varied forms, varying in style, substance and scale, reveals shared histories with the planet's peoples and cultures in the developed and developing worlds. Biotechnology has a long history. Old as the growing of crops and the making of cheese and the production of wines, its practice has been described as one of the oldest professions in the world. *Modern Biotechnology*, in general, embraces more often the principles and practise of genetic engineering. Several other terms such as genetic engineering; genetic transformation; transgenic technology, recombinant DNA technology, and genetic modification (GM) technology have been used to describe the applications of this form of modern biotechnology.

Issues of significance such as the conservation of the environment, the energy crisis, expansion and migration of populations, use of agro-residual resources, ocean agriculture, global warming, water security, biowarfare,

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and emerging diseases have somehow made it to the top of the agenda of international co-operation. The perennial problems of widespread starvation linked to poverty are back again in the wake of globalization, biotechnology and high-powered summit meetings. Novel agriculture, genetic modified organisms (GMOs), GM crops and products, and bio-based economies have been spotlighted by governmental attention and public action in recent UN and international forums. The UN Human Development Report 2001 (HDR) "*Making New Technologies Work for Development*" identified biotechnology as a key avenue for the socio-economic advancement of the developing countries.

Biotechnology in Developing Countries

Biotechnology enriching the way we do and teach science, and considered as the latest frontier of the corporate world, is full of entrepreneurial opportunities for networking the technological advancement and transformation of the developing world. Such opportunities arise from simple yet spectacular research in microbiology and molecular biology which closely intertwine with those from information technology and nanotechnology and this intertwining has been described as *bionanomatics*.

The enzymatic machinery of the invisible microbe and the unlimited use of genetic tailoring are being tapped to redesign solutions for sustaining soil fertility and boosting crop yields. Current focus is on molecular *pharming* to produce new a wide range of bio-products ranging from biofuels, bioplastics, biodiesel, biodetergents, and biolubricants, to biopharmaceuticals and bio-ornamentals. Novel crops already reflect the fruits of research in plant and floral architecture. Reliance on the use of GMOs in achieving sustainable development is on the increase in particularly the developing world. Growth of the gene-based pharmaceutical market, assessed at US$2.2 billion in 1999, for treatment of diseases not possible in the past, is now projected at $8.2 billion in 2004. Plant-derived vaccines scheduled for administration through GM-foods, and possibly soon through breakfast cereals, will conserve more human resources at a fraction of current, and sometimes inhibitory, costs. Simply eating a banana or a potato chip with tomato paste could result in a patient receiving a Hepatitis-B needle-free

vaccine for two cents instead of the usual US$15 estimated for an injectable dose. In fact, GMO technology has spurred economic progress in the technically-advanced societies notwithstanding strong opposition to its application in agriculture.

Generally-speaking genetic engineering techniques have been applied to crops of the industrialized world rather than to those on which the world's hungry depends on. Corporate research activities in agricultural biotechnology, seemingly profit-oriented, and as a response to the voices of poverty-prone and poverty-stricken millions, that are at the frontlines of national development and international cooperation, begin to involve resource-poor farmers from developing and least developed countries in agricultural education and research schemes that help to protect their meagre household incomes, to better use new knowledge in producing higher yields of pest resistant crops, and to improve local gender and socio-economic conditions. Hunger in these countries, results from a complex situation of interconnected factors —lack of adequate purchasing power, poverty, non-availability of back-up financial facilities, low crop yields, and a deteriorating environment.

There are many developing countries, especially in the African continent, that are known as the low-income food deficit countries. These countries possess neither the ability to produce sufficient food to feed their own populations nor the foreign-exchange reserves to import food supplies to cover the food deficits. President Jimmy Carter said: "Responsible biotechnology is not the enemy, *starvation is*. Without adequate food supplies at affordable prices, we cannot expect world health or peace". Several of these low-income food-deficit countries are poverty-prone or poverty-stricken. Poverty in urban areas in coming decades will overtake rural numbers.

GM crops and foods have many benefits for the developing world such as: enhanced market possibilities coming from higher crop yields; the use of clean, green and safe bioprocess technologies; improvement in the quantity and quality of meat, milk, and livestock production and a reduction in dependence on fossil-derived fertilizers and herbicides. Benefits arising from use of GM technology are: conservation of and an increase in the

valuable savings of poor-resource farmers. Also, there is a wider environmental impact through development of clean technologies. Moreover, there is safety assurance that there is no current evidence that transgenic crops contain new allergens other than those in normal foods nor have a negative impact on human health.

In the next two decades, the changing face of agriculture will emerge more fully. GMOs are being widely used in the European Union (EU) and in several developing countries. Gene-altered crops rice, wheat, beet, potato, tomato, corn, peanut, rapeseed, sweet pepper and cotton in China have been cultivated over a 10-year period, since 1986 to boost agricultural yields. Recent documented data shows that "developing nations accounted for 24 percent of biotech crop acreage in 2000, up from 18 percent the year before" and that, "in fact, developing nations accounted for 84 percent of the new acreage planted to biotech crops in 2000". In the three poles of the southern hemisphere- Latin America and the Caribbean, Africa, and Central and Southeast Asia, some 20 developing countries are engaged in gene-based agriculture. Field trials with transgenic cotton, maize, potato, soyabean, tomato, banana and sugarcane have taken place in Argentina, Brazil, Belize, Bolivia, Costa Rica, Chile, Cuba, Dominican Republic, Guatemala, Mexico, Peru and Uruguay. China, India, Indonesia, Malaysia, Phillipines and Thailand have embarked on trials with cotton, corn, potato, soyabean and tomato. Field trials with bananas, corn, sweet potatoes, and fast-growing trees have been planned or initiated in Egypt, Kenya, Malawi, Nigeria, Senegal, South Africa, Swaziland, Tanzania, Uganda and Zimbabwe. Gene-modified trees are of value in forest ecosystems, plantation use and landscape development and novel cultivation sites. The naturally occurring argan tree—Argania spinosa in Morocco is an example of a potential new tree crop in saline agriculture.

MIRCENs – Launch and Extension to Island Territories

The concept of the MIRCEN network was launched in 1975. It has emerged from a once pilot network of 8 nodal research and training laboratories on the five continents into a global infrastructure that involves over 30 national,

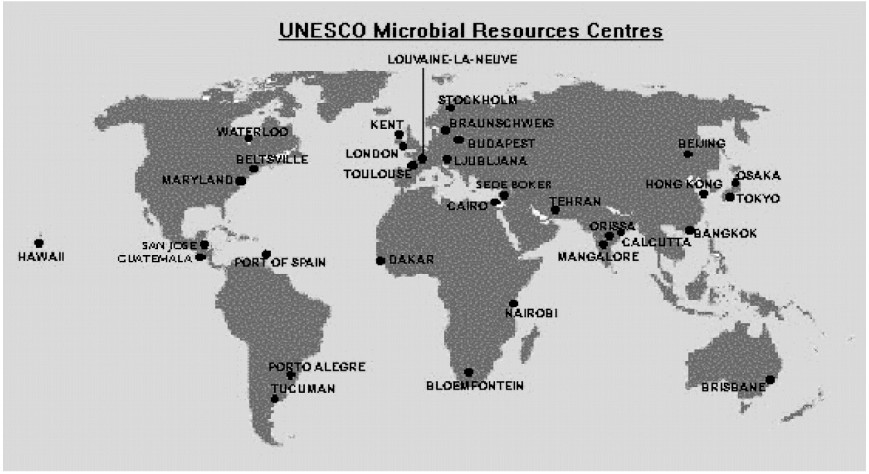

Fig. 1. The UNESCO MIRCEN network

regional, and international centres in 26 countries (fig.1). The pilot network included key nodes of research and training in Brazil, Egypt, Guatemala, Kenya, Senegal and Thailand.

These MIRCEN centres are devoted to the mission of conserving, managing, distributing, and utilizing the diversity of the microbial gene pool for the benefit of humankind. Also, there is no doubt that the network of microbial resource centres plays an important role in the evolution and transformation of *global village microbiology* into today's *global class of biotechnology*. The scientific output of the MIRCEN network of academic institutions and universities are many, and result from working together with a large number of governmental, non-governmental, scientific institutions and universities that have already been described in detail elsewhere. Several MIRCENS located in the developing world are engaged in a wide range of activities (*see Annex*).

Lessons learnt, within the framework of regional and international perspectives and viewpoints, indicate that there is a need for capacity-building and of disseminating the use of good practices concerning the scientific, legal, and ethical aspects relating to the use of the biotechnologies. The challenge and need for devising educational and capacity-building

schemes that enable developing countries to embark, possibly in network cluster groups, or in twinning arrangements with the industrialized countries always exist since the scope and scale of technical literacy in biotechnology varies amongst countries in a region. Once account has been taken of their level of research in biotechnology of their capacities to produce and to commercialize biotech products of their degree of participation in developing national, regional and international biotech governance dealing with biosafety, conservation, trade of genetic diversity and ability to engage in national education and regional training schemes, developing countries are well on the path of economic and sustainable development. The catalytic and contributory efforts of the MIRCEN Network in this domain have been amplified through the collaborative and cost-sharing educational and research initiatives set up with institutions such as the African Association for Biological Nitrogen-Fixation (AABNF), American Society for Microbiology (ASM), the UNESCO Biotechnology Action Council (BAC), The Electronic Journal of Biotechnology (EJB), the International Union for Microbiological Sciences (IUMS), and the Biotechnology Division of the Research and Information System for the Non-Aligned and Other Developing Countries (RIS).

The world of islands in the developing world is comprised of communities in rural or semi-urban areas where agriculture and aquaculture are the main economic activities. The application of biotechnology to these two scientific "cultures" would help to upgrade traditional practices into self-sustaining market ventures that generates much needed capital.

In Africa, the island nations of Cape Verde, the Comoros Islands, São Tomé and Principe and Seychelles are characterised by their small size and fragile ecosystems that limit their individual commercial production possibilities thus making them very susceptible to economic conditions and pressures elsewhere in the world. Their individual insularity and remoteness lead to high transport costs of a very narrow range of exports, and to a vulnerability reflected in an excessive dependence on imported energy and raw materials. Nevertheless all is not bleak. These island countries constitute examples of the least developed countries, notwithstanding globalization

and its implications, that have accepted the challenges of development and technological advancement (*Table* 1). Indeed, as articulated by the Executive Secretary of Economic Commission for Africa, in the Millennium Lecture Fulfilling Africa's Promise (17 December, 2001) "Africa must be part of the global future of science-based progress. Our most basic economic task is to sustain food security, possible only by bringing science to agriculture. Africa has not really benefited from the Green Revolution. So we may have to leapfrog that revolution—for ecological and economic reasons—and embrace the next agricultural revolution, the Biotechnology Revolution. We need a massive scaling up of poverty-focused public sector genetic research. We need strong and open debate on safeguards, to gain public support for the results of research. And because development in Africa has so far failed to embrace modern science to solve African problems, we need to establish—or re-establish—regional centres of excellence for science and technology research.

In the Arab world, Bahrain is the only island state in the world of the Arab nations. Endowed with an economic resource of export significance, Bahrain, by virtue of it geographic location, occupies a significant commercial and security role in regional collaboration and international cooperation. Bioresources and biodiversity in the island territories in the Arab world of Oman (the *Dimaaniyat Islands*), Saudi Arabia (the *Jurayd Island Chain*), and Yemen (the *Kamaran and Socotra Islands*) are also described (*Table* 1).

The MIRCEN initiative in the Caribbean region was launched as part of the political commitment when, over a decade and a half ago, the Grenada National Commission for UNESCO, representing the general agreement of Caribbean Ministers responsible for UNESCO Affairs and the Member States in the Caribbean sub-region, resolved that "an extension of the international network of resources centres (MIRCENs) *be created in the Caribbean region*". In implementation of that decisive resolution, participants in the workshop "Perspectives for Biotechnology in the Caribbean", held in Port of Spain, Trinidad and Tobago, February 1988, articulated a regional strategy focusing on the following priority areas:

- micro-propagation and tissue culture of plants;
- integrated pest management;
- nitrogen-fixation, enzymology and germplasm conservation; and
- antisera and diagnostics

The plan, "Caribbean Development to the Year 2000: Challenges, Prospects and Policies", emphasized the general absence of innovation in Caribbean industry. In consequence, several Caribbean island countries have resorted to the systematic application of biotechnology. The Caribbean nations consist of more than 25 island states with varying populations that depend on a rich diversity of plant genetic resources for their nutrition, health and well-being. The English-speaking Caribbean includes a number of small politically independent island territories that have largely agriculture orientations. Plantation crops, such as sugarcane, banana, cacao, citrus and spices were the mainstay of the economies of these island in the pre-independence era. Post independence, whereas agriculture continues to be an important activity that generates considerable employment, tourism and other industries have evolved as important earners of foreign-exchange in other territories. Other economic pursuits coupled with population expansion have led to a considerable reduction in arable land and holding size in these territories, making plantation agriculture uncompetitive. Global trends towards trade liberalization have further aggravated the situation and necessitated the transformation of agriculture in the English-speaking Caribbean. Traditional plantation crops that require economies of scale to be globally competitive are being replaced with non-traditional niche crops, such as ornamentals, exotic tropical fruits and crops targeted at small ethnic but precious markets in North America.

The Caribbean, home to a rich variety of fruit, vegetable and ornamental crops, is amongst the richest regions of biodiversity in the world. Unfortunately, much of this biodiversity is threatened by hurricanes that cyclically and routinely ravage the Caribbean islands. Micropropagation, thus seemingly, is the mechanism of safeguarding against loss of crop genetic diversity in the wake of hurricanes in the Caribbean region. Thus there has been a reliance on tissue culture which has been used as a mechanism of conservation and as an economical tool for the micropropagation of many

food and ornamental plants in the region (*Table* 1). Another recent development is research into the methods for food preservation and extension of the shelf-life of plant products. The Mona and St. Augustine campuses of the University of the West Indies are involved in joint ventures with industry in the production of white potatoes, ginger, banana, and yarn. The banana producing and exporting states in the Caribbean region-Belize, Dominica, Grenada, Jamaica, St. Lucia, St. Vincent and the Grenadines, and the Windward Islands, are plagued by a variety of geographical and economic disadvantages that are uncommon to their Central and South American competitors. Crop production on steep terrain and small family venture farms, e.g. in the Windward Islands, continues to be the backbone of several rural economies and the socio-political fabric of a number of the Caribbean island countries.

The nations of the Pacific region share substantial constraints in terms of scientific, technological, managerial, and economic resources necessary for sustainable, island-wide, maricultural and maritime development. To meet these drawbacks, consideration has been given to initiating appropriate developmental and educational issues that use biotechnological and microbial applications meet human, nutrition, food safety and energy needs. About nearly two decades ago, a survey by the MIRCEN at the University of Queensland, Brisbane, with the help of the Australian National Commission for UNESCO, Massey Universtiy and Cawthron Institute in New Zealand and the government authorities of some 20 Pacific island nations, established the following priority areas for educational and research activities:

- agricultural biotechnology ranging from plant improvement to agro-processing and soil fertility;
- biodegradation;
- fermentation ranging from the production of industrial alcohol to food, feed, and fertilizer;
- treatment of waste waters;
- microbial product formation; and
- aquaculture from algal production to fish breeding and cultivation within the framework of a Pacific MIRCEN Biotechnology Network.

Table 1.Range of biotech activities of islands in African, Caribbean and Pacific regions

Island country	Vulnerabilities	Outlook solutions	Remarks
Bahrain	Effects of climate change	Enabling activities related to conservation of biological diversity	Global Environment Facility (GEF)
Cape Verde	-Loss of fish stocks -Loss of biodiversity	- Fishery management at Mindelo, São Vicente, Fogo & Brava islands - Conservation of biodiversity involving containment of land depletion and arrest of loss of biodiversity	- In co-operation with FAO and the governments of Germany and Norway - Project with UNDP and GEF
Comoros Islands	Loss of valuable biodiversity	Island Biodiversity and Participatory Conservation through establishment of model national parks and biodiversity trust funds	Development of frameworks for conservation and sustainable use of biodiversity
Dimaaniyat Islands (Oman)	Endangered avian species and nestling nurseries for turtles	Development of Dimaaniyat Islands Reserve	Government-sponsored and funded programme
Dominica	Exposure to fluctuations in climatic conditions and market economy prices	- Agricultural, Horticultural and Crop Extension Project - Accelerated propagation of pineapple and papaya seedlings to farmers - Sweet corn production increased with reduction in consumer prices	1995 Banana crop destroyed by Hurricane *Luis* - National Pineapple Growers' Association assists in pineapple cultivation and ensuring compliance with market quality control protocols

Table 1 continued

Table 1 continued

Island country	Vulnerabilities	Outlook solutions	Remarks
		- East Caribbean Micro-credit project which aims at reduction of poverty, self-employment and improvement in living standards	- Provision of loans to micro-enterprises in the agricultural industry *Project partner countries*: Grenada, St. Christopher and Nevis, and St. Vincent and the Grenadines.
Dominican Republic	Uncertainty of economic and governance priorities; Exposure to market price fluctuations	- Rice Seed Improvement project - Introduction of hybrid rice varieties and propagated seed at Nigua, La Vega and San Juan - Horticultural Crop Cultivation Project - Development of heat-resistant garlic varieties and garlic cultivation techniques - Field demonstrations of organic agriculture of vegetables, and watermelon cultivation - Aquaculture Development project - Development of aquaculture skills to raise tilapia, species of common, grass and silver carp, and fish fry - Raising stocks of red tilapia and common carp at Higuey work station	- Project establishes a rice seed fund - Training opportunities provided by Department of Agriculture In co-operation with Department of Agriculture: - Establishment of Production zone in 2001 of fish farming zone at Nigua Experimental Centre - Establishment of laboratory for training in monitoring water quality, and detecting fish diseases

Table 1 continued

Table 1 continued

Island country	Vulnerabilities	Outlook solutions	Remarks
Grenada	Exposure to inclement climatic conditions erodes Agricultural outputs of bananas, cocoa, citrus, mace, nutmeg, avocados, sugarcane and corn	- Agricultural Processing project: - Establishment of a fruit-juice processing plant as part of the diversification strategy of technology and economy	- In co-operation with the Department of Agriculture
Haiti	Dependence on the agricultural sector Neglect of the proactive environment	- Rice Yield Extension Project - Improvement of rice yields in drive to self-sufficiency Mechy experimental farm - Provision of training to rice farmers from the Artibonite valley on cultivation of rice variety *Taichung Hsien 10* - Bamboo cultivation project handicraft and ornamental - Provision of seedlings of *Cassia, Green, Putai,* and *Taishan* species and *Dendrocalamus latiforus* - Water Development and Supply Project - Improvement in the quality of potable water	Development of cultivation technology and testing, evaluation and certification of stocks at the - Development of women entrepreneurs - Development of self-sufficiency-based enterprises of farmers - Emphasis on monitoring water quality and supply in Port-au-Prince and Jacmel City .
Jurayd Island Chain (Saudi Arabia)	Endangered avian species and threatened nestling nurseries of green turtles	Development of the six coral reef island chain as the Jubail Wildlife Sanctuary	Government sponsored and funded programme

Table 1 continued

Table 1 continued

Island country	Vulnerabilities	Outlook solutions	Remarks
São Tome and Principe	Poverty-prone and -stricken	- Rural Development to Combat Poverty - Pilot project for food crop development - Support to Poto Research Station to provide on demand pedological and phytopathological analyses - Artisanal Fisheries Development	- Activities supported by FAO and the International Fund for Agricultural Development (IFAD)
Seychelles	- Turtle species endangered - Susceptible to climate change - Loss of endemic plant biodisversity	- Biodiversity Conservation and Marine Pollution Abatement that targets the protection of hundreds of species e.g. turtle species not found elsewhere - Enabling Activity to build technical capacity and strengthen national institutions concerning climate change issues - Propagation, nursery and establishment protocols for Seychelles endemic plants - Management of Avian Ecosystems to improve the conservation status of threatened endemic birds	- In co-operation with GEF, Darwin Initiative Eden Project (UK), UNDP, and World Bank
Socotra Archipelago (Yemen)	Loss of rare and precious biodiversity	Sustainable development of Socotra Island involving large-scale inventory and assessment of the island's biological resources	Project activities in partnership with Birdlife International and the Royal Botanic Garden Edinburgh (UK); UNDP/GEF

Table 1 continued

Table 1 continued

Island country	Vulnerabilities	Outlook solutions	Remarks
St. Christopher and Nevis	- Economy dependent on sugarcane and its decreasing market prices - Destruction of the sugarcane crop by Hurricane Georges in 1998	- Fruit and Vegetable project: - Propagation of seedlings and nursery seedling development at Needs must - Provision of training in management and technical skills at Fahies and Nevis	Known as the "Silico Valley of the East Caribbean" in view of its electronic manufacturing sector
St. Vincent and the Grenadines Regional - *Caribbean region*	Dependence on the banana crop is the biggest impediment to economic development	- Horticultural Development project - Development of extension fruit and vegetable activities at Dumbarton and Pembroke for development of seedlings, market surveys and technical training with pepper and sweet potato crops. - Department of Agriculture expands plant tissue culture laboratory	- In the biennium 1994 – 1995 tropical storms wiped out crop plantations - In co-operation with the Department of Agriculture tests made with seeds of alfalfa and mung bean - Seedlings of banana widely distributed - Major pineapple breeding program initiated, and new focus on passion fruit, wax apple, India jujube and carambola
CARDI	Loss of potential floral, food and ornamental markets	Priority is given to the production of "clean"planting material of improved varieties. The CARDI tissue culture	The Caribbean Agriculture Research and Development Institute (CARDI) established in 1975 and based in

Table 1 continued

Table 1 continued

Island country	Vulnerabilities	Outlook solutions	Remarks
		laboratory in Barbados, serves as a repository for virus-free yam material, and germplasm storage of selected crop species of economic significance. It supplies plantlets of banana and anthurium plants to Dominica, St. Lucia, St. Vincent, Grenada and Trinidad and Tobago. CARDI laboratories in Grenada and St. Vincent and the Grenadines focus on banana micropropagation; and those in Barbados and St. Lucia propagate ferns, anthuriums and orchids to meet local and regional demands	Trinidad and Tobago has been a pioneer in the development of plant biotechnology in the region. CARDI provides research and development services to the Member States of the Caribbean Community and Common Market (CARICOM).
-Indian Ocean Oil Spill Contingency Planning and Management Programme	- Loss of coastal and marine ecosystems - Loss of planktonic biodiversity and food chains	- Development of capacity building to protect and sustain the biologically rich coastal and marine ecosystems of the four Western Indian Ocean Islands - Plankton Biodiversity; taxonomy and data evaluation	*Programme partners* : Comoros, Madagascar, Mauritius and Seychelles with GEF support - Mauritius and Seychelles in framework of Darwin Initiative, UK
Global Coral Reef Monitoring Network (GCRMN)	- Loss of biodiversity and marine ecosystems and endangerment of coral reef network niches	Coral Reef Monitoring Network in Member States of the Indian Ocean Commission (COI), within the GCRMN.	*Network partners*: Comoros, Madagascar, Mauritius, Seychelles with GEF/World Bank support

Seemingly, these requirements could be easily met by a transfer of existing microbial technology or the design and development of new appropriate microbial processes (Doelle, 1989). A reality-check, however, reveals that each of these areas requires an infrastructure that is not optimally developed throughout the Pacific Region. For example, study and research at the College of the Marshall Islands (CMI) in the area of biotechnology on local breadfruit, pandanus, banana, and vegetable crops is in its very early stages. The Republic of the Marshall Islands (RMI) is rich in marine biodiversity that has many plants that play a significant role in the Marshallese culture, medicinal practices and traditions. The RMI does not currently have any laws or regulations addressing GMOs and, therefore, its fragile environment is highly susceptible to alterations that may be caused by the incidental or intentional release of GMOs.

A recent Asian Development Bank (ADB) (Gillet 2001) study found that the contribution of the fisheries sector to the economies of the Pacific islands is often underestimated and noted that " this lack of awareness need not be a problem. It is not necessary for everyone to fully appreciate the significance of any activity in the economy. However, when that lack of appreciation extends to policymakers, planners, and development agencies, it can mean that fisheries development receives lower priority than it deserves". Thus, one of the biggest ironies in the region is the lack of full appreciation of the value of fisheries to the economy by policymakers and planners.

Development Challenges

A World Bank report on *Bioengineering of Crops*, in 1998, indicated the value of bioengineering in an improvement of 25 per cent in food crop yields in developing countries. A year later the Bank, through a report entitled "Agricultural Biotechnology and the Poor", drew attention to biosafety and ethical issues. In July 2000, a report on Transgenic Plants and Agriculture prepared by the Royal Society of London, the U.S. National Academy of Sciences, the Brazilian Academy of Sciences, the Chinese Academy of Sciences, the Indian National Science Academy, the Mexican

Academy of Sciences, and the Third World Academy of Sciences also emphasized the importance of GMO technology enhancing agricultural benefits in developing countries.

As concerns issues of biosecurity, GMOs have been amongst the first beneficiaries of biosafety assessment. Guidelines and directives issued by several international and UN agencies, inclusive of the FAO/WHO Codex Alimentarius Commission the universally accepted authority that sets the necessary standards. Nevertheless, the negative rather than the positive aspects have been retained, as is typical of human wants, in the public mind. Loss, of plant biodiversity resulting from economic reliance on a GM species for production of fruit juice; and of landscape diversity arising from demands for more land for public housing and transportation, have little to do with GMO ill effects on human health. As President Carter said in 1998: "If imports [of GMO seeds] ... are regulated unnecessarily, the real losers will be the developing nations. Instead of reaping the benefits of decades of discovery and research, people from Africa and Southeast Asia will remain prisoners of outdated technology. Their countries could suffer greatly for years to come. It is crucial that they reject the propaganda of extremist groups before it is too late"

In summary, the negative features of use of GMOs are: loss of crop genetic diversity; economic loss of evaluated biodiversity and crop genetic diversity; threat to use of generic medicinal products, inadequate compensation costs, alteration in nutritional quality of foods; prevalence of religious, cultural, ethical issues (*i.e.* with vaccines and single-cell protein (SCP) and concerns of monopolistic ownership of the 15 major food and non-food crops.

Public concern and debate in industrialized societies on environmental uncertainties and health risks of use of GMO technology should not discourage the developing world from reaping benefits from using GM crops and GMOs to solve their pressing problems of hunger and malnutrition. Much needed public education and understanding of GM food science through appropriate science education programmes could help. After all, humankind, unwittingly, has been eating genetically-modified foods since

the dawn of agriculture as exemplified in wheat, which from the early days of wild wheat, then through einkorn and emmer wheat, and then through spaghetti wheat and bread wheat has finally resulted in biotech wheat. The challenge of development as posed by the deployment of biotechnology and the issues of GMOs, as underlined by Prime Minister A. B. Vajpayee in his inaugural address to the 89th session of the Indian Science Congress (Lucknow, 3 January, 2002) "calls for responsible" advance of biotechnology which does not expose our ecology and society to major risks……We need a responsive and regulatory enforcement mechanism, which brings together researchers, policy makers, NGOs, progressive farmers and the government to help ensure that the benefits of biotechnology reaches all our people quickly……The new responsible biotechnology, must take care to avoid a genetic divide".

References

DaSilva, E.J. 1998. Biotechnology: Developing Countries and Globalization. World Journal of Microbiology and Biotechnology, Vol 14: 463 - 486.

Doelle, H.W. 1989. "Socio-economic biotechnology development for developing countries". MIRCEN Journal of Applied Microbiology and Biotechnology, Vol. 5, pp. 391-410.

Gillet, R. and Lightfoot, C. 2001. *The Contribution of Fisheries to the Economies of the Pacific Island Countries*, A Report prepared for the Asian Development Bank, the Forum Fisheries Agency and the World Bank, published by: Asian Development Bank, Manila, December.

ISAAA Brief. 2001. Global Review of Commercialized Transgenic Crops: 2000, No. 23 - *www.isaaa.or*)

UNDP. 2001. UN Human Development Report, UNDP, United Nations Plaza,, New York., USA.

Annex

The 2002 Microbial Resource Centres – MIRCENS in Developing Countries

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The Culture Collection MIRCENS

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