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REVIEW ARTICLE

Biotechnology and the developing world

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The life sciences offer opportunities for revolutionizing human welfare activities. Enriched by inputs from genomic research, biotechnology is a major force for development in all countries. Entwined with culture and socio-ethical values, biotechnology contributes to solving problems like food and water insecurity that impede national development and threaten peace in the developing world. The lack of facilities and professional skills in biotechnology limits R & D initiatives in the developing and the least developed countries (LDCs); and, restricts their full participation in take-off activities in national and self-reliant regional ventures in sustainable development. The practice of biotechnology different in many developing countries is nevertheless impressive. The establishment of biotechnology parks and medicinal plant farms in several developing countries is indicative of biotechnology being accorded high policy status in national development; of its significance in the eradication of poverty; and of its use in the empowerment of women in applying the technology for human and social welfare. This review provides several examples of different types of biotech activities that are being employed for development in the developing world.

Advances in the life sciences offer opportunities for revolutionizing human welfare activities primarily through improvements in the quality and quantity of healthcare. Notwithstanding the availability of these knowledge-rich developments, arising from research in especially molecular biology and microbiology, global problems such as food and water insecurity and the advent of new and re-emergent diseases impede national development in the developing world. Slow resolution of these problems damages the environment, weakens social infrastructure, and constitutes a threat to peace. The UN Human Development Report (HDR) "Making New Technologies Work for Development" (UN, 2001a) identified biotechnology as a key avenue for the socio-economic advancement of the developing countries. A goldmine of opportunities in the corporate world, biotechnology enriches the way we do and teach science which has emerged as a global player on the international scene. The enzymatic machinery of the invisible microbe and genetic tailoring are increasingly being used to obtain a variety of bio-based products (DaSilva, 2001). Biotechnology, varying in scope, scale and practice in many developing countries, is full of entrepreneurial opportunities for the technological progress of the developing world.

Hunger, poverty and food security

In many developing countries, and inclusive of those in the Islamic world, biotechnology has become a source of economic development and social progress (DaSilva, 1997, 1998) providing access to technology on credit and peer markets to especially rural poor entrepreneurs (Holaday, 1999; Lalljee and Facknath, 1999). Poverty-stricken rural populations are confronted with inadequate water resources (Serageldin, 1999), low crop yields, food shortages, food insecurity, a deteriorating environment, and hunger (Box 1).

Over 80 low-income food-deficit developing countries (LIFDCs) possess neither the ability to produce sufficient food to feed their own populations nor the foreign-exchange reserves to import food supplies to meet the deficits. The sub-Saharan region, susceptible to political instability and weak economies, is most vulnerable since it is home to about 25% of the population in 67 low-income developing countries that are poverty-prone or poverty-stricken. In sub-Saharan Africa, people living on less than

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US$ 1 a day rose from 242 million in 1990 to 290 million in 1998 (WIDER, 2001). In comparison, the number of people, in East Asia, fell from 452 million in 1990 to 278 million in 1998. Poverty in urban areas, emerging in some industrialized societies, is soon expected to overtake rural numbers in the coming decades. Food production, population and poverty are closely connected (Table 1).

Opportunities and constraints in agricultural biotechnology in developing countries are of significance in responding to the challenge of poverty in the 21st century (Persley and Lantin, 2000) as they influence the development of national strategies that minimize environmental, health and social risks; and that address the nutritional needs of poor-resource farmers. The United Nations Decade for the Eradication of Poverty Decade (1997 - 2006) focuses on the environment, development, human rights, and vulnerable groups. In the Horn of Africa ----- Djibouti, Eritrea, Ethiopia, Kenya and Somalia, about 70 million people suffer from malnutrition, food scarcity and famine in harsh and inhospitable climates not conducive for efficient agricultural productivity (FAO, 2000). Resilient communities live under harsh drought conditions e.g. little rainfall, soil erosion, and lack of access to opportunity in farming. Combating poverty involves actions to increase food security; to improve the availability and quality of basic services; to generate opportunities for sustainable livelihoods: to empower rural women in gaining land credit, in accessing training, commercial markets, emerging technologies, and in participating in community decision-making processes. It is in this context that biotechnology can make a contribution. As 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".

Profit-oriented agricultural biotechnology is now addressing poverty, food insecurity, conservation of the environment, and sustainable development. The involvement of resource-poor farmers from LDCs in the design and formulation of field trials; their education and financement as transmitters of new knowledge, of good practices, and productive services in rural communities is now being encouraged in international programmes. Co-operation between the United Nations Development Programme and the West African Rice Development Association (WARDA) has resulted in the production of a New Rice for Africa (NERICA) variety that was obtained by crossing African and Asian species. Designed for resource-poor farmers, this new protein-rich variety is tolerant to drought and acid soils, and generally resistant to a wide range of African insect pests.

Active participation in community development assists in the way out of poverty. Karanja et al (2000) described close collaboration with participating NGOs in co-financed experimental trials in four Senegalese villages. In village-based science education exercises over 330 farmers, inclusive of 140 women farmers, were exposed to environmental and societal benefits resulting from the use of biological nitrogen-fixation technology. Also Land to lab technical sessions, with a focus on environmental bioremediation, and employing the principles of show and tell, and earn and learn, were organized by the local scientific community for some 2000 farmers from the villages of Balapur, Kelzar, Sawanga, and Talodi during an international conference on global sustainable biotechnology in Nagpur, India. These demonstration/training/information-cum-service activities are catalytic and rewarding for rural farmers and folk. Different kinds of technology, new crop varieties, floriculture, aquaculture and micro-enterprises such as mushroom production are tested with the active participation of eager to learn villagers. Talents and skills, individual and collective, are crucial to the constructive evolution of an important bridge between the rural poor and local governance, and between rural educational and urban research institutions. In India, UNDP pioneered the biovillage approach in 1999 with the Pillayarkuppam village in Pondicherry. Eighteen other villages, with a population of 25.000 people, participated in the biovillage experiment that provides technological empowerment; that transforms village communities into ecological entrepreneurs; that augments individual rural resources with additional incomes that improve gender involvement; and that contribute to food security through rural production of safe and nutritive food. Emphasis is on achieving food security through an inexpensive and uninterrupted access to nutritious and wholesome foods for use in daily food intakes by all communal segments. Success in ensuring food security has been noted in several developing countries (FAO, 1996).

Plant biotechnology, which is one of the many approaches involved to solve the complex problems of hunger, poverty and food insecurity, may be an appropriate technology within reach of rural and disadvantaged farmers. Use of low-risk and low-cost biotechnology techniques such as micropropagation could be beneficial. There are many instances of plant biotechnology enabling small farmers in Argentina, India, Morocco, and Uganda to obtain increased and sustainable crop yields. In the Democratic Republic of the Congo, tissue culture plays a vital role in helping establish food security that was affected by war and subsequent neglect. Cassava clones, obtained from the International Institute of Tropical Agriculture in Nigeria, are propagated as disease-free plantlets to start-up crop productivity which is maintained through use of crop protection techniques (FAO, 2001). In Kenya, tissue culture of disease-free banana plantlets has helped raised yields, and secure farm household incomes threatened by the dwindling loss of the coffee cash crops. Co-operation between the Kenya Agricultural Research Institute and the South African Institute of Tropical and Sub-Tropical crops has helped former coffee-growing farmers to use biotechnology for development, and to make the transition in earning new income. And, co-operation between the International Potato Centre in Peru and Ugandan National

Agricultural Research Organization has resulted in the introduction and growth of disease-free potato crops in the Kabale District of southwest Uganda. In all three examples, the training of Congolese, Kenyan and Ugandan farmers in low-cost plant biotechnology techniques features prominently in long-term co-operation. A case study of how biotechnology can benefit the poor and the hungry (Wambugu, 2001) indicates the potential of biotechnology in tackling poverty and hunger (Spillane, 2000).

GMOs in agriculture and development

GMOs (known also as Living Modified Organisms -LMOs) are obtained from parent animals, plants and microorganisms. Concerns, fears, and promises expressed with GM crops and foods are not voiced with fermented foods that are prepared in near-safe hygienic conditions and that contain whole or parts of natural organisms. Debate concerning GM crops and foods is emotional and fierce (Box 2), public and technical (Skeritt, 2000). Opposing arguments focus on the economic loss of crop genetic diversity and biodiversity; the threat to the use of generic medicinal products; the indiscriminate appropriation of native intellectual property resources and absence of adequate compensatory measures; non-conformity with religious, cultural, and ethical issues, and monopolistic trends given that 10 top life science industries have ownership of 15 major food and non-food crops.

There is a continuing need of safety assessment of GM foods and products to address health hazards possibly arising from the release of GMOs into the environment (WHO, 2000). Nutritional and safety assessment require a comparative approach between such foods and their conventional counterparts (FAO/WHO, 2000). An integrated stepwise approach in quality control, inclusive of random control trials and periodic updates in safety assessment, helps in assuring and securing the safety of GM foods in the public sector. Restriction in the imports of GM products has been introduced in Brazil, and imports of GMOs have been banned in Sri Lanka pending further review in relation to environmental and food safety (Anderson and Yao, 2001). In the industrialized societies and some developing countries public protest has led to demands for risk-assessment research in the cause-effect phenomena associated with GM crops; and subsequent stricter regulation has resulted in differing transatlantic viewpoints (Levidow and Carr, 2000). With emphasis on the safety component in GM agriculture, some developing countries are in the process of drafting biosafety guidelines whereas others have enacted formal issuance. GM agriculture is not new. In practice over several thousands of years by Mother Nature and mindful of Gregor Mendel's principles of inheritance, GM agriculture has developed rapidly from the applications of the techniques of genetic engineering in crop improvement. Benefits encountered are: improvements in the quality and quantity of meat, milk and livestock production; low dependence of poor-resource farmers on expensive chemical-based fertilizers, and enhanced market potential. Ancillary benefits are an environmental motivation for development of bio-based clean technologies, and defined methodologies for evaluation of the allergenicity of foods derived from biotechnology (FAO/WHO, 2001; Schlundt, 2001).

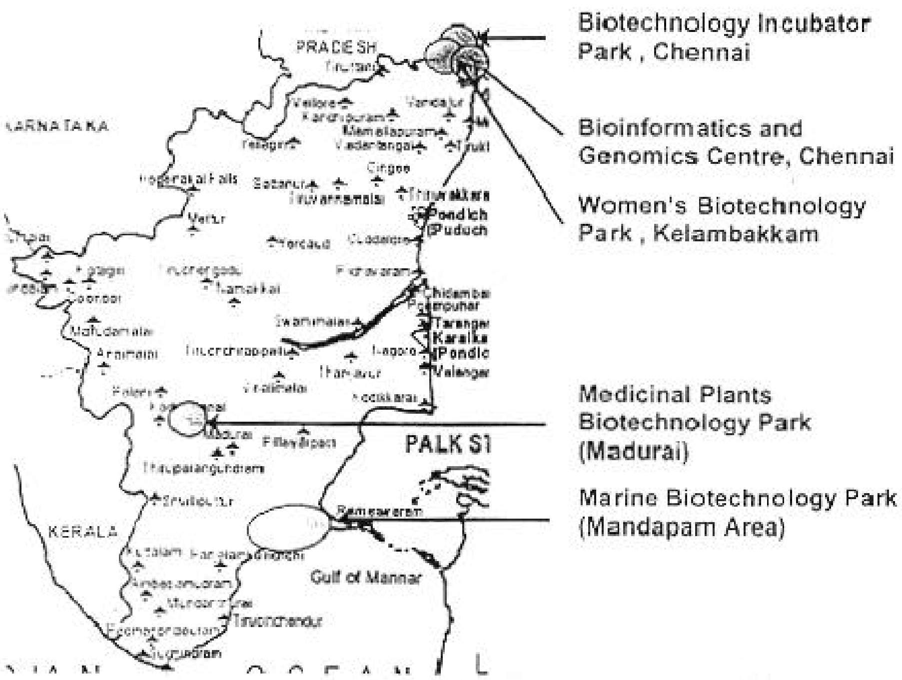
Several developing countries have embraced GM agriculture (Krattiger, 1994). Some 160 GMO releases have been conducted in about 25 developing countries. Field trials with transgenic cotton, maize, potato, soybean, tomato, banana and sugarcane crops are reported in Argentine, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Guatemala, Mexico, Peru, Trinidad and Tobago, Uruguay and Venezuela. In Africa, the Arab States and Asia —China, Egypt, Ghana, India, Indonesia, Kenya, Malawi, Malaysia, Mozambique, Nigeria, Senegal, South Africa, Thailand, Uganda and Zimbabwe are engaged with 5 transgenic crops: cotton, corn, potato, soybean and tomato. And in countries in transition to development in Eastern Europe ----Bulgaria, Romania and the Ukraine, field trials, in 2000, had just begun or were scheduled to get underway.

Today, over 50 million hectares of GMO crops are grown worldwide involving especially Argentina, Canada, China and the USA. The developing countries' share amounts to 24%. In China, over 50 per cent of all crops are assumed to have been engineered genetically. Gene-altered crops --- rice, wheat, beet, potato, tomato, corn, peanut, rapeseed, sweet pepper and cotton crops have been grown since 1986. Research in India with GM crops ----rice, rapeseed, potato, eggplant, cauliflower, chilly, and tobacco is being conducted at several academic, governmental and private institutions with built-in biosafety and monitoring protocols. Indonesia, became the first Southeast Asian country to produce a GM crop —cotton, commercially following successful trials conducted in the districts of Bantaseng, Bone, Bulakumba, Gowa, Soppeng, Talakar and Wajo by the Hasnuddin University and Universitas Gadjah Mada. GM fruits ----avocadoes, pineapples and mangos exist. GM plants constructed with bioremediating functions help protect the environment and the plant.

GM plants planned for release are expected to improve food yields in developing countries by up to 25%. These include caffeine-free coffee plants, tobacco plants containing a diabetes vaccine, and soybeans with a "heart-friendly and healthier" oil profile and an improved digestible protein content.

Arid land and desert biotechnology

The Middle East, with its varied characteristics in culture, economies, the environment, governance and religion, is home to semi-urban and urban agriculture that seems to have originated in the Fertile Crescent of the Middle East homeland of the first farmers (Wilford, 1997). Rich in the eight founder crops: wheat, barley, legumes, grapes, melons, dates, pistachios and almonds, this crescent area,



(*Source*: *www.biotechpark.com/policy%20 document.html0*)

Figure 1. Outlay of Women's Biotechnology Park in Chennai, India.

nurtured through farming initiatives and routine practices, some 9,000 years ago, evolved into a successful agricultural movement of domesticated animals and plants that spread to other regions (Bogucki, 1996).

Arid lands and deserts make up a large part of Africa. Two-thirds of the continent is desert or drylands. Half the continent's population is found in these areas. Also, some of the poorest countries in the world, with heavy population growth, meagre national resources, a weak or negligible technological base, primary level education, and inadequate technical infrastructures, are found in Africa (Box 3). A combination of natural hazards --- cyclic periods of droughts and floods along with over-cultivation and over-grazing have transformed once fertile substrates into dry and sterile desert-like soils.

Agriculture in several arid African developing countries is linked to water availability and security. Vulnerability of agricultural and water resources, ecosystems, food production, utility goods, shelter, and human health is high in regions with weak infrastructures. Several of these African water-stressed countries are dependent on a singular economic base ----agriculture, which in dryland Middle Eastern OPEC countries exists along side an additional naturally occurring export-value resource---oil. The African dryland LDCs, do not have the economic means nor the well-defined strategies to respond effectively, in time, to the onset of malnutrition and poverty, and to the recurrence of vector-borne diseases. Agriculture, in these countries which have a low livelihood base and inadequate socio-cultural services, is further disadvantaged by fragile ecosystems and the phenomenon of globalisation. Against this background, the use of GM technology could make a beneficial impact through the use of improved seeds and disease-free high-quality plantlets to grow high-value commercial crops in low-rainfall areas. In addition, rural education could help promote the benefits of such technology in diversifying complementary agricultural practices such as fisheries and floriculture. Arid and semi-arid countries are known to benefit from the production of high-quality tissue culture reared plantlets; from the seeding of rural biotech industries e.g. ornamentals and floriculture which provide complementary sources of income for women; from the production of GMOs for food production; and from the production of alternative products such as biodiesel, biofertilizers, biopesticides, etc. Examples of activities in dryland agriculture are provided in Table 2.

The containment of desertification in arid lands occurs in the ability to bioconvert their ecological disadvantages in to economic benefits coming from the cultivation of desert crops; development of saline agriculture and aquaculture, and the rational use of water, wastewater and other water resources. Seawater agriculture or the growth of salt-tolerant crops on land with ocean waters, and of a variety of halophytic crops ---grasses, shrubs and trees encountered in coastline marshes or in saline desert terrains is full of promise. (NAS, 1990). Grasses and plants such as: Distichlis palmeri (salt grass), Salicornia (glasswort), Atriplex (saltbush), Suaeda (sea blithe), and the succulent Batis (saltworth) are used to supplement meagre feed intakes of normal palatable plants in livestock feeds. Halophyte farms of Salicornia and Atriplex species have been established in Egypt, India, Mexico, Pakistan, the United Arab Emirates, and Saudi Arabia (Glenn et al, 1998). Sea-water agriculture in China involves almost 300,000 hectares of coastal land in the Hainan, Hebei, Guandong and Shandong provinces. Of economic importance in coastal agriculture, halophytes are cultured for landscaping and as fodder in Egypt; as ornamental plants in Morocco; and for greening and landscaping arid soils in Tunisia, Saudi Arabia and the UAE (Table 3). In Chile, the leguminous tamarugo tree in the Atacama desert is being tested for resource development with the Aymara communities; in Senegal biofertilizer inoculants are being developed for application in Middle East soils; and in Pakistan similar material is being prepared for use in desert agriculture in Kazakhstan. Several initiatives exist concerning the greening of desert lands (Table 4).

Biotechnology parks and medicinal farms

In the continuing quest for economic advancement and technological development, several developing countries have embraced the concept of biotechnology parks that combine scientific enquiry with R&D biotech savoir-faire to yield potential market products. With this raison de faire, biotechnology parks use an amalgam of entrepreneurial energies and networking skills to promote co-development of biotech processes, to transfer biotech know-how, and to provide technical services. In brief, biotechnology parks incorporate incentives that provide for an academic environment unencumbered by bureaucratic guidelines; that transform concepts and ideas into environment-friendly bioindustries, and that attract start-up angel, seed and venture capital, and tax exemptions. Biotechnology parks in several developing countries reveal a political commitment in transforming the potential of modern biotechnology knowledge into reality for the benefit of all strata of society (Table 5).

The Government of Tamil Nadu, and the Department of Biotechnology, Government of India approved in 1997 the establishment of the first Women's Biotechnology Park in the country at Kelambakkam, near Chennai. The Park (Figure 1), which came into being in July 1998, aims to develop an integrated approach involving technology identification, incubation, dissemination, training and retraining, development of necessary techno-infrastructure through feasibility studies using the criteria of value addition and market demand. The park, designed on the principle of decentralized production with support from relevant centralized services, promotes a series of high-tech biotechnology-based enterprises aimed at capturing a number of markets in the areas of Ag-biotech, Food biotech, Medical biotech etc. Moreover, the Park will host industrial incubation centres, an ultra modern multimedia information complex, and quality verification reference laboratories. The R&D institutions, the corporate sector and the financial institutions will assist the women entrepreneurs to achieve the objectives of the Park serving primarily as a model to foster the technological and economic empowerment of women.

The main objectives of this biotechnology park are to bring together women entrepreneurs, scientists, financial sponsors and industry for purposes of generating openings for skilled employment of women. Moreover, since women and children are traditional conveyors of domestic science education and technology in the food and energy domains, and of the agriculture and the environmental sectors in rural areas, application and use of proven biotechnologies is encouraged in achieving the technological empowerment of women. The park also serves as a training centre promoting regional economic growth and collaboration between women entrepreneurs in the formulation of appropriate market strategies for marine and medicinal plant products.

Medicinal plants have been used, since times immemorial in virtually all cultures as a source of medicine. Herbal remedies and plant-based healthcare preparations obtained from traditionally used plants, have been traced to the occurrence of natural products with medicinal properties (Box 4). Moreover medicinal plants and herbal remedies are re-emerging medical aids whose contribution and significance in the maintenance of good health and well-being is widely accepted (Hoareau and DaSilva, 1999). "Herbal medicines can provide effective treatments for insomnia, skin conditions, and burns to travel sickness, depression, and liver, back and prostate problems. Medicinal plant extracts have also been found to boost the immune systems of people suffering from a range of diseases ---AIDS" (Anon, 2001).

The Brazilian medicinal germplasm program focuses on ethnobotanical studies, germplasm characterization. and in situ conservation. The Brasília Botanical Gardens and EMBRAPA, in 1994, established an in vivo collection of medicinal plants from the Cerrado biome for the screening the occurrence of phytochemical anti-inflammatory principles and other medicinal agents. In Morocco, the Ministry of Higher Education and Scientific Research in cooperation with the European Union, recently finalised the establishment of a research institute devoted to medicinal plants in Taounate, Fez. Of the known 42,000 species of Moroccan plants, some 800 are used in the medical and perfume industries. In the United Arab Emirates, the Zayed Complex for Herbal Research and Traditional Medicine has modernized its facilities in upgrading the complex to an international center. Long-term plans involve the:

- Study of patterns of medicinal plants use by traditional healers in the UAE
- Research in compatibility between orthodox medicine and traditional medicine
- Preparation of a national Herbal Pharmacopoeia

- Identification of curative entities in locally used herbal extracts and formulations
- Development of a small-scale production unit with clinical trial facilities, and
- Establishment of quality control procedures and safety standards for local products developed at the complex, and imported herbal medicinal products

In Mpumalanga, South Africa, a large-scale propagation co-operative facility for medicinal plants was launched in 2000 with the production of medicinal plant seedlings being estimated at 1 million per month. Accessibility to parent stock holdings under the control of the South African National Parks and the Mpumalanga Parks Board has been granted to the facility to enable local farmers, rural communities and practitioners of traditional health medicine benefit from its programme activities.

In the industrialized societies, the use of traditional medicine and medicinal plants in the treatment of minor ailments is now more acceptable since such use helps lower the increasing costs of personal health maintenance. In the 1990s the use of complementary herbal medicine soared with consumption doubling in Western Europe. Much of the supply of herbal medicine results from random and wild harvesting in Bulgaria, Poland, Hungary and former Yugoslavia which uncontrolled practice leads to damaged plant roots that in turn result in low regeneration rates, and eventual long-term economic and environmental disasters. A Medicinal Plants Act has been brought in to force in Albania and Bulgaria; and, almost all Central and Eastern European countries now have legislation protecting endangered plants through organized harvesting that also provides a supplementary source of income for the women labour force. For example, a women's herb-growing co-operative in Bosnia and Herzegovina is financed through UK non-governmental aid. To build up stocks of medicinal plants and to guard against economic losses have many medicinal plants are conserved, maintained and propagated in medicinal plant farms and parks (Table 5).

Gender and biotechnology

The "LDCs greatest assets are their women, men and children whose potential agents and beneficiaries of development must be fully realized" (UN, 2001b). Efforts in developing resources of much needed human capital in LDCs are affected by low school enrolment, low health, and lack of adequate nutrition and sanitary facilities. Natural and man-made disasters, communicable diseases like malaria and tuberculosis along with the prevalence of the HIV/AIDS pandemic, especially in Africa, have eroded precious human resources. Women and children in most LDCs occupy a central role. Natural and normal transmitters of traditional civic customs and values, women are crucial in the assimilation and acceptance of new technologies as is evident from the range and number of TV advertisements aimed at women. In rural and village communities, women provide the first example of working together in a co-operative venture as they make ends meet with inadequate incomes (Box 5).

Women in rural and lower middle-income societies make an economic contribution to agricultural and healthcare markets. Women farmers collect, keep, store, conserve and sow seeds for use by peasant societies. Women healers are, the keepers and providers of traditional knowledge concerning herbal- and plant-based medicine, and fermented foods. Their food recipes and medicinal preparations are closely guarded secrets that have been handed down from generation to generation and which are at the basis of sustaining nutritional and health inputs virtually on a daily basis. Indeed, women in rural and village biotechnology are the primary food producers, food gatherers, and food processors, worldwide throughout the developing world. Women, not masters of their own time, plant, weed, help harvest and even see to crop sales.

Similarly in the energy sector, women trudge miles in search of biomass bush material as a source of fuel for cooking and other domestic purposes. Application of biotechnological principles, on the one hand, releases rural women from the drudgery of tiring manual labor in the energy and food sectors, and on the other hand provides them with more opportunities for cultural, societal, and technical education in improving the quality of family and community life (Zweifel, 1995).

In several developing countries, especially in Asia and Africa, gender plays an important role. Women, by nature, are involved in the selection, conservation, and management of plant biodiversity ranging from food crops to medicinal plants. Application of automatic mechanization and genetic engineering lessens and weakens the role of skilled rural women in agriculture. In the biotechnology park in Kerala (see Table 5), the state government, promoting wider participation of skilled women desirous of working in night shifts, amended the Commercial Establishments Act removing the restriction in force for over five decades.

In Belize the Medicinal Plant project with the Bio Itzá Mayans of San Jose, focuses on reviving the near extinct Maya Itzá language and arresting the declining use of medicinal plants. The latter is achieved through an inventorisation of traditional Itzá medical knowledge; a photographic reference book for community use; and visits to other Mayan communities that have established medicinal plant-based pharmacies. More than 275 medicinal plant species -- herbs, vines, and trees, have had their details registered with some 430 natural remedies being identified. A women's committee oversees the management of a medicinal plant garden, the housing of each medicinal specimen in a herbarium; the construction of an ethnopharmacy; and the creation of worthwhile jobs. Acceptance and appreciation of skilled women managers lead to spin-off commitments to protect the environment; to provide assistance to the threatened Mayan culture; and to bring affordable and effective plant-based treatments within reach of village communities.

In India women, preferentially, opt for career development in the life sciences. Mathematics, the engineering sciences and space technology attract more the male component of the cream of Indian scientific humanpower rather than potential women scientists. The role of women in biotechnology in the developing world is "to provide opportunities for professionally qualified women to take to a career of remunerative self-employment through the organisation of environment friendly biotechnological enterprises" as defined in the mission statement of the UNDP-UNIFEM (United Nations Development Fund for Women) meeting of women scientists at the M. S. Swaminathan Research Foundation at Chennai, December, 1996 concerning the establishment of a Women's Biotechnology Park commemorating the 50th anniversary of India's independence.

Strategic biotech initiatives in the developing world

Developing countries are already devising and using strategic biotechnologies to solve problems of local, regional and global significance (Table 6). The European Union (EU), through the Lome Convention, promotes technical co-operation with 70 countries in Africa, the Caribbean and the Pacific (ACP). Research institutes and universities are engaged in competitive breakthrough peer-reviewed research are constantly attracting scientific excellence. The horizontal flow of research amongst and between developing countries strengthens South-South regional and international collaboration which involves diversification of agricultural production, industrial enterprises and a well-developed human resource base. Self-sufficiency and self-reliance, the twin hallmarks of a "stand alone" market-oriented economy are crucial and can be achieved only through co-operative networking and sharing of experiences, and knowledge-rich resources.

Capacity-building in biotechnology for development

Biotechnology is a cross-cutting technology encountered in wide application across several sectors of development. An amalgam of a variety of disciplines -biochemistry, the engineering sciences, genetics, informatics, molecular biology and microbiology, the neurosciences and nanotechnology amongst others, biotechnology makes important contributions to the new knowledge-based economy and markets.

Developing countries, and especially the LDCs, face challenges in setting up the agendas of international co-operation in deriving benefits from biotech markets. The lack of professionals, sophisticated equipment, relevant infrastructure, deficiency of national legal instruments concerning patents and intellectual property rights, and of financial support widen rather than bridge the gap of R & D in biotechnology between the industrialized and developing countries. Hence there is a distinct need for education and capacity-building — important elements in the use of biotechnology for development.

The style, substance and scale of biotechnology in the developing world varies within a region, and from region to region. Hence the need for devising educational and capacity-building schemes that enable developing countries embark on sustainable development, possibly in network cluster groups once account has been taken of their level of research in biotechnology; of their capacities to produce and commercialize biotech products; of their degree of participation in developing national, regional and international biotech governance dealing with biosafety, conservation and trade of genetic diversity; of their capability and capacity for national education and training; and of their ability to engage in regional research since the scope and scale of biotech literacy varies amongst countries in a region. Many of the advanced developing countries, unlike several LDCs, have well established centres and institutions with the capability to educate and provide training on general and specific issues.

Life spans of research capacities in Cameroon, Ethiopia, Ghana, Kenya, Malawi, Nigeria, South Africa, Uganda, and Zimbabwe in plant biotechnology are limited in scope and are donor-dependent. Strengthening of existing capability and capacity to engage in contemporary agricultural research, to institute biosafety mechanisms and new management of research in biotechnology would influence availability of future donor support in these countries (Komen et al, 2000). Institution of periodic internal and external peer-review of programme planning and performance would help strengthen the emergence and sustainability of competence in agricultural biotech research, and help attract participation from the private sector. Such available capacity e.g. in Indonesia, Kenya, Mexico and Zimbabwe would drive application of contemporary biotechnology with a pronounced user focus as well as attract back African expatriate biotechnological expertise (Falconi, 1999).

In today's climate of competitive biotechnology and development, many of the advanced developing countries are faced with new challenges and problems as they engage in cutting-edge biotech research and participate in global biotech governance and technology systems. Environmental management and building of capacity in intellectual property rights are two areas of significance. The goals of environmental considerations are to increase productivity, protect the environment, safeguard against loss of biodiversity, and improve environmental policies and strategies concerning:

- Socio-economic issues such as the population growth, poverty, bioethics
- Scientific issues such as GM foods and biosafety Education and training of rural and urban communities in the use of biotechnology and understanding of genetic engineering
- Developing market-oriented ventures e.g. aquaculture, cash crops, and landscaping and ornamental materials; biotech reagents
- Environmental governance to protect heritage, traditional knowledge, intellectual property rights
- Governance and networking management of by rural communities of natural renewable and non-renewable resources

Research in biotechnology has also highlighted the need for attention to intellectual property rights that cover patents, copyright, database rights, design rights, trademarks and confidential information and processes. There is a need for clarity on how biotech research knowledge is generated, shared, and owned, and on the possession of proprietary rights in relation to natural resources and compensation costs.. Recent experiences of some developing countries on biotech issues precipitated by the use of genetic engineering with non-protected natural resources and biodiversity e.g. with the neem tree and fragrant long-grained rice, has emphasized the need of safeguarding indigenous traditional knowledge and its use in the absence of adequate compensation costs. Also in many developing countries patent law is either outdated or non-existent. There is a need for training biotech entrepreneurs in the value and usefulness of patent and intellectual property legislation. Though several developing countries are signatories to international conventions, enactment of subsequent national legislation is slow or still in the pipeline. Lessons learnt indicate there is a clear need for capacity-building and of good practices in the scientific, legal and ethical aspects concerning intellectual property (Kornhauser, 2001).

In the advanced or newly industrializing developing countries, the support to the generation of scientific knowledge has served as a sort of precursor in fostering a culture and desire for development. Building of research infrastructures and scientific and high-quality biotech institutions takes years of commitment and investment in development. Many of the more developed of the developing countries some five to six decades ago possessed a different level of capacity and capability to use biotechnology for development. Emphasis was then on training and developing future generations of scientific cadres, and building up institutions and centres. Networking in the biosciences with developed countries in the North America, Europe and elsewhere through bilateral and UN programmes was a critical and crucial factor. Today some of these advanced developing countries, within the framework of South-South co-operation can play a similar role in aiding the LDCs and small island countries which alone cannot develop the wide range of range of the biosciences and biotechnology that they need.

Developing countries and LDCs are already devising and using strategic biotechnologies to solve problems of local, regional and global significance (Box 6). Their participation in several regional and international pedigree programmes contributes to an on-stream worldwide resource that reflects to some extent, the human face of globalization. Flexibility, scientific co-operation, and co-shared funding help developing countries respond to the common challenges that involve biotechnological solutions for the benefit of all humankind. South-South collaboration and capacity-building in technical development and economic co-operation programmes have proven useful in the transfer of biotechnology (Rath and Lealess, 2000).

Conclusion

Biotechnology is a motor of technological advancement in both the developed and developing countries though at different levels in scope and content. The simple production of cheese and fermented foods to the industrial production of antibiotics and the genetic elaboration of biopharmaceuticals and novel crops illustrate the breadth and depth of biotechnology endeavor and practice worldwide. One of the three new technologies that impact on our lives on virtually a daily basis in the international arena, biotechnology (and the life sciences) influence developments and issues in interactions between Europe and the USA, and between the developed and developing worlds (Schneider, 2000). Apt examples are the attention to the safety of GM foods and to the prevalence of AIDS by the G8 summit in Okinawa, 2000; and to the use of GM agriculture in the USA, and its introduction into Europe and the developing world. Some decision-makers and scientists see biotechnology as an effective means to combating hunger, malnutrition and poverty; others call for more detailed approaches and studies. Though the latter viewpoint is of significance in the short-term, there is no doubt that in the long-term biotechnological applications in the agricultural, food, energy and health sectors will lead to economic, environmental and social benefits when addressing the needs of the poor. In a sense, this conclusion is reflected in the establishment in several developing countries of biotechnology parks that are examples of pro-poor biotechnology and pro-industrial programmes for development.

In the developing world many developing countries have lagged behind on account of unsuitable socio-economic conditions, inadequate infrastructure and political will, and absence of financial resources. Several others are advanced or have made progress in the practice and use of a range of practices in biotechnology for development:

- African Lions: Gabon (immunology); Kenya (biofertilizers); South Africa (genetic engineering, ornamental plants); Senegal (biofertilizers)
- Arab Stallions: Egypt (genetic engineering); Bahrain (marine biotech); United Arab Emirates (biosaline agriculture)
- Asian Dragons: China (Shanghai Biotechnology Park; national biogas programme); Hong Kong (window to Southeast Asia and Pacific-Rim Biotechnology)
- Asian Elephants:India (Government Department of Biotechnology, Women's Biotechnology Park; national Bioinformatics programme, Institute of Microbial Resources); Indonesia (environmental biotechnology)
- Asian Tigers: Malaysia, Republic of Korea, Singapore, Thailand (Advanced in genetic engineering and varied biotechnologies; ASEAN database in each member country)
- Latin American Jaguars: Argentine, Brazil, Chile, Costa Rica, Cuba, Mexico (Well advanced in molecular biology, genetic engineering, production of commodity chemicals (ethanol), and immuno-diagnostics)

One of the main factors perpetuating poverty, hunger and population growth in the developing countries is the lack of education and of time for education. Exposure of farmers and the rural scientific community to biotechnological education would inculcate an appreciation of the science of biotechnology for development. Capacity-building programmes would go a long way in eradicating doubts and fears of the use of biotechnology in different fields. Capacity-building, for example in the acquisition and use of GMOs in sgriculture and their assessment in field trials and effect on humans and in the environment may elicit a response opposite to that expressed in the absence of such education and training. Through national capacity-building programmes, regional networks and international co-operation with the Consultative Group of International Agricultural Research Centres (CGIAR), UNESCO's global MIRCEN network (ATAS, 1992); FAO's REDBIO and the Global Forum for Agricultural Research, developing countries can harness the potential of biotechnology as an effective tool for solving problems of hunger, poverty and disease. Gradual progress and successes will bear out the importance of biotechnology in the long-term for national economic growth and development. Also it is time for developing countries to become more pro-active in identifying their strengths, competencies and weaknesses in setting the agenda and speed in harnessing biotechnology for their own scientific and national development.

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Appendix I - Boxes

Box 1: Hunger, Poverty and Population

Hunger

· One amongst every six persons, in the developing world, has no access to food

· Of 830 million people suffering from malnutrition and hunger
--- 790 million live in developing countries, often, home of the poor and hungry
--- 80 million children under 4 years of age are malnourished

· The ***undernourished*** subsist on 1,800 calories per day or less instead of a general requirement of 2000 per adult per day

· At the World Food Summit (1996), 186 countries committed pledged a reduction by half in the number of undernourished people by 2015

Poverty

· As a ***rule*** hunger is a direct consequence of dire poverty

· Seventy per cent of the world's poor live in rural areas

· Poverty, essentially a rural phenomenon, is creeping into urban areas

· 2.8 billion people live on less than US$ 2 per day

· Of the 1.3 billion people in the sub-region of South Asia

--- 800 million live on less than US$ 1 per day
--- 230 million lack access to safe water
--- 100 million children live or work on the streets

· In 1998, the 48 poorest countries attracted less than US$3 billion in foreign investments

· Poverty in urban areas in coming decades will overtake rural numbers

· Some 650 million people in Asia (300 million), in Africa and Latin America (150 million each) live in urban areas below the internationally- accepted poverty line of US$1/day

Population

· Of the approximately 90 million newborn, 95% are born in developing countries

· 40 million births each year are not registered world-wide

· 70% of people in the developing countries below the poverty line are rural women

· Of the approximately 1100 million farmers worldwide
---50 million farmers are in the developed world
---1050 million farmers with little financial resources are in the developing countries

· By 2050, two-third's of the world's population is likely to be urban

· 90 per cent of the world's population will begin life in a developing country

· Developing countries account for about 78 per cent of the world's population

Sources: ----Common Fund for Commodities (1996), Novartis (2000); Union of Concerned Scientists (2000), White Paper (1997); World Food Programme (2001), WMO (2000).

Box 2. GMO considerations

- Benefits poor-resource farmers in use of number/amount of herbicides/pesticides
- High yields and more productive crops are part of the solution to the global food crisis
- No evidence that commercial transgenic crops contain new allergens nor have negative impact on human health
- Genetic engineering techniques generally are applied to crops important to the industrialised world, and less to crops on which the world's hungry depend
- Global GM crop area estimated to be a little over 50 million hectares
- Fears concerning GM foods and crop result from:
  - Occurrence, spread and ignorance of *Mad Cow Disease* in Europe
  - Reported occurrence of chemical dioxin in foods ,soft drinks; sludge in animal food
  - Inclusion of GM food in animal in food for humans (*tortillas*)
  - Concentration of seed companies in a few hands
  - Lack of, and/or inadequate tests of GM crops in tropical environments
  - Improper identification and labelling of GM foods in food markets
  - Absence of public awareness and consumer education programmes

In summary, "*the use of the newer biotechnological techniques does not result in food which is less safe than that which is produced by conventional ones*"

Source: Extract from a joint FAO/WHO Consultation (5 –19 November, Geneva, 1990) Report: *Strategies for assessing the safety of foods produced by biotechnology*, WHO, Geneva, 1991 (*http://www.who.int/fsf/GMfood/*).

Box 3. Arid Lands

- 70% of the earth's dryland is affected by desertification
- 1 billion of the world's 6 billion, in more than 100 countries, is affected by desertification
- Loss in agricultural goods, due to desertification, is more than US$40 billion p.a.
- Of the 42 high in-debt countries, 39 are located in tropical desert regions
- Farmers are faced with the problems of soil erosion, plant viruses, high-cost chemical-based fertilizers and pesticides
- Deforestation, pollution of soil with toxic wastes, urban development, etc., are principal factors in the loss of arable crop land

Source: UN (2000)

Box 4. Medicinal Plants

- 80% of the world's people rely on traditional medicine for their daily health needs
- In the 1990s consumption of herbal medicine in Western Europe doubled
- About one in four of all prescription drugs dispensed by Western pharmacists are likely to contain ingredients derived from plants
- *Chamomile* harvest provides some 15,000-20,000 people with work each year in Hungary
- Some 150 medicinal plants in Europe are considered to be endangered
- The global market for medicinal markets is expected to grow from US$ 10 billion in 2001 to US$40 billion in 2010 with Europe accounting for a large part of this market

Sources: Anon (2001).

Box 5. Women in Partnership with Biotechnology

- *African proverb*: Without women we all go hungry
- In developing countries women produce 75% of the food
- In African-Caribbean-Pacific (ACP) economies women produce 80% of staple foods
- Women work two-thirds of the world's working hours, earn one-tenth of the world's income and possess less than one-tenth of the world's property
- Rural women in Africa (*Burkina Faso*) in processing shea butter from *Butyrospermum parkii* help establish direct competitive links to global markets
- In the Andean region an estimated 40 per cent of women agricultural producers play an important role in food security
- In Asia 90% of the work in rice fields is carried out by women
- In Europe, the women of Pudojevo, Kosavar find economic security in the agricultural sector
    - 40 per cent of some 180 women farmers are household heads and sole economic providers for their families
- Up to 70 per cent of the world's poor are women
- Some 900 million women have incomes of less than US$1 per day
- As the male component moves to urban areas for better incomes or to serve in war, women constitute the new generation of farmers in several LDCs
- Women are custodians of traditional knowledge that is of significance in rural medicine
- In sub-Saharan Africa, 55 per cent of those living with HIV/AIDS are women
- Biotech medicines and diagnostic aids are helping women to improve their health and thus the quality of their lives

Sources: Swaminathan (1998); UNIFEM (2000); White Paper (2000).

Box 6. Transfer of Technology in South-South Co-operation

- Use of Senegalese fish-smoking technique to meet local taste preferences of traditional community in Ghana
- Transfer of biogas technology from China to Brazil and Costa Rica, and from India to Cambodia
- Development of the "Ear-lift" unit in Thailand, and subsequently used with success in Lao People's Democratic Republic and Kenya
- Development of the "Jaipur foot" prothesis in India and its technology transfer to Malaysia and Thailand
- The Africa/Asia Joint Research Project: interspecific hybridization between African and Asian Rice Species for developing radically new low-management, high-yielding varieties of rice e.g. *Nerica*. The new rice varieties possess ability to suppress weeds, resist diseases and environmental stresses, and due to their increased height, help women (with babies on their backs) without bending to harvest them more easily. In 1997/1988, the project supplied back-cross progenies to Asia, Latin America and seventeen African nations including Benin, Burkina Faso, Cameroon, Ivory Coast, Gambia, Ghana, Guinea, Guinea Bissau, Nigeria, Sierra Leone, and Togo
- In Latin America and the Caribbean, the Centro de Ingenieria Genetica y Biotecnologia (CIGB) and the Carlos Finlay Institute in Cuba co-operate with ELEASA, an Argentinian pharmaceutical company to find commercial channels for their biopharmaceutical products
- In the South Pacific, twenty -two small island developing states, in co-operative initiatives in marine biodiversity, have provided training to approximately 10,000 people per year in the framework of the University of the South Pacific Marine Study Programme at the University of the South Pacific through regional institutions like the South Pacific Commission, the South Pacific Environment Programme, and the Forum Fisheries Agency
- The Brazilian-Argentinean Centre for Biotechnology (CABBIO), an association of firms and individuals, jointly funded by the two governments and privately run, has developed a joint venture partnership between Biotica (Argentina) a small research-oriented firm specializing in vegetable micropropagation and new potato seed technology with Sementes Agroceres (Brazil) a leading manufacturer of agricultural seeds and animal food. The partnership has developed, tested, and marketed in Brazil a new variety of potato seed accounting for 2% of the Brazilian market and competing successfully with imports from Europe.

Source: Rath and Lealess (2000)

Appendix II – Tables

Table 1. Population growth and food production.

Year	*Author*	*Essay/Report*	*Remark*
1798	Thomas Malthus	*Essay on the Principles of Population*	Proposes that human fertility would outstrip human ability to produce enough food
1972	Club of Rome	*The Limits to Growth*	Mass starvation could result from unchecked growth
1983	Amaryta Sen	*Essay on Entitlement and Deprivation*	Poverty, not shortage of physical food, is the cause of hunger
1990	P.R. and A.H. Ehrlich	*The Population Explosion*	Focus on population problems vis-à-vis food availability and production
1996	World Bank	*Food Security for the World*	Solution to hunger is distribution of purchasing power to the poor
2000	Jonathan Latham	*"More Food Means Less Hunger"*	"There's enough food for all, but the poor cannot afford to buy it".

Table 2. Arid land biotechnology- examples of regional activities.

Organization	Biotechnology Activities	Countries
Association of Agricultural Research Institutions in the Near East and North Africa (*AARINENA*)	Development of wheat cultivars resistant to leaf and stem rusts in the Nile Valley and Red Sea Regions	*Cyprus, Jordan, Iraq, Lebanon, Palestine, Syria; Djibouti, Egypt, Sudan, Somalia, Yemen*
	Arab Peninsula Region	*Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, UAE*
	West and Central Asia Region	*Afghanistan, Iran, Kazakhstan, Kyrgystan, Pakistan, Tajikistan, Turkey, Turkmenistan, Uzbekistan*
Asia Pacific Association of Forestry Research Institutes (*APAARI*)	Strengthening of regional networks working with cereals and legumes, maize and underutilized fruits	*China, India, Indonesia, Iran*, *Malaysia, Philippines, Thailand*
Central Asia and Caucasus Region (*CACR*)	Agriculture has a dual function in economic development i.e. the production of food, and the provision of gainful employment	*Armenia, Azerbaijan, Georgia, (Caucasus), Kazakhstan, Kyrgystan, Tajikistan, Turkmenistan, Uzbekistan (Central Asia)*
Regional Forum on Agricultural Research and Development (*FORAGRO)*	Agriculture is a key component of economic development in Latin America and the Caribbean	Member countries in Latin American and the Caribbean

Table 3. Examples of halophytes in use.

Halophyte species	Purpose of use	Region of growth and use
Atriplex angualata	Fodder plant	Australia
Atriplex nummularia	Fodder plant	North Africa
Atriplex semibaccata	Fodder plant	Argentine, Bolivia, Chile
Noronhia emarginata	Ornamental	Madagascar
Pithcolobium dulce	Landscape tree, fodder for animals, curry, dye, glue	India
Salicornia fruticosa	Vegetable oil production	North European coastline and France**
Tamarix aphylla	Furniture wood, wind shelter in plantations, firewood	Arab countries

Source: Cash Crop Halophytes for Future Halophyte Growers -Leith, H, Lohmann, Güth, M, and Menzel, U., -EC ICI8CT96 -0055 project /UNESCO MAB program (partners:UNESCO/MAB; Institut fur Umweltsystemforschung, and University of Osnabrück)
**Introduced into more than 40 countries

Table 4. Some initiatives concerning the greening of desert lands.

Country	Climatic Feature	Species	Remarks
Cape Verde	Group of islands with desert-like low rainfall	*Prosopis trees*	Joint Project: Cape Verde National Institute with Henry Doubleday Research Association (HDRA), UK; Women are the main beneficiaries
China	Saline soils	Interplantation of amaranthus grain and trees	Shandong Teachers University project with HDRA
	Gobi desert	*Nitraria siberica*	Pastoral shrub
India	Thar desert	*Prosopis cineraria*	Cross trials with between Oman and India using drought-resistant trees
Israel	Negev desert	*Balanites aegyptica, Vitelleria paradoxa*	Oil producing trees being domesticated
		Date palm Sahel project	Date palm programme with Burkina Faso, Tchad Cameroon, Mali, Mauritania, Niger, and Senegal
Mexico, USA	Chihuahua desert	*Artemisia ludoviciana, Berberis trifolia,*	Landscape plants, research in desert ecosystems
		Cernis canadensis var. mexicana, Ephedra torregana	Desert medicinal plants

Namibia	Namib desert Kalahari desert	*Welwitschia mirabilis* *Scleorocarya birrea*	Soil conditioner Developed with Israel as an orchard crop. Fruit exploited as source of food supplements
Oman	Wahiba Sands desert	*Prosopis cineraria*	Bark provides edible gum; joint project with Sultan Qaboos University and Durham University (UK)

Source: DaSilva (2002)

Table 5. Examples of biotechnology park and medicinal plant park initiatives by developing countries.

Country	*Feature(s)*	*Location*	*Remarks*
Brazil	Promote R&D in biotech business through transfer of technology and research expertise to the private sector.	Polo Bio Rio Park, Rio de Janeiro	First biotech industry park established, over a decade and half ago in Latin America. Overseen by Brazilian Biotech Industry Association with support from Brazilian Association of Science Parks and Institutes
China	Biotechnology Financing Zones planned in Taiwanese science parks with focus on development and commercialization of high-quality biotech products:--Hepatitis B vaccine, diagnostic kits, herbal and medicinal drugs	Changwa coastal industrial park Hsinchu science park Tainan science park Tainan technology park Yunlin technology industrial park	Sponsored by Taiwan Industrial Development Board
	Development of a Biotech Valley Concept for food, medicine, floriculture, agribiotech, bioprocessing of raw materials	Yunnan area which includes the Kunming Hi Tech Incubation zone, and the Kunming Economic zone with planned biotech corridor that links up research centres and several industrial parks	Approved and financed by Central Government
	Institute of Medicinal Plants established in 1983	Medicinal plant farms in Yunnan, Hainan and Guangx provinces	Recognised WHO Collaborating Centre on Traditional Medicine

Egypt	Commercialization of Biotech research results for targeted end-users	Establishment of a specialized BIOGRO Unit at the Agricultural Genetic Engineering Research Institute (AGERI), Giza, to interact with the Genetic Engineering Science Unit (GESU) for speeding up commercialization of high-quality products and services	Sponsored and maintained by AGERI
	Transfer of research into resource businesses and products; biotech markets need to be developed	Development of biotechnology in bio-based incubators established in Assiut, Banha, and Mansoura University; science industrial parks planned	Egyptian Incubator Association
	Use of best practices in management of medicinal plants in St. Katherine's protectorate in the Sinai Farmaya Laboratory	Conservation of medicinal plants in arid ecosystems; management of endangered plants; establishment of small /medium -scale enterprises; protection of intellectual property rights in medicinal plant parks	Programme activities administered by the Egyptian Environmental Agency (EEAA) with support of the Global Environment Facility (GEF) and the United Nations Development Programme
Guatemala	Farmaya Laboratory	Organic cultivation of medicinal plants, pharmacological research, production of plant-derived pharmaceuticals, development of protocols for safe use and screening of 700 different plants. 15 pharmaceutical products developed using traditional knowledge of indigenous and rural groups	Collaborates with Central America Centre of Studies on Appropriate Technologies; National Commission for Use of Medicinal Plants serves as a model for Latin American countries in developing guidelines for plant-based pharmaceuticals; Co-operates in IDRC project on *Application, Research and Dissemination of the Use of Medicinal Plants in the Caribbean.*

India	Manufacturing of innovative biotech products	Biotechnology Park at Turkapally, Andhra Pradesh	Sponsored by Andhra Pradesh Government
	Harnessing of the benefits of biotechnology to provide self-employment openings to women entrepreneurs	Women's biotechnology park, Chennai	Sponsored by Tamil Nadu Government,Department of Biotechnology (Govt of India); Tamil Nadu Industrial Development Corporation and M.S. Swaminathan Research Foundation
	Development of new biotech industries; Emergence of entrepreneurs in genomics, biofuels and biotech contract services	2 biotech-bioinformatics parks at Bangalore and Dharwar, and a marine biotechnology park at Karwar, Karnataka	Sponsored by University of Agricultural Sciences, Bangalore: Insititure of Agricultural Biotechnology, Dharwar: and Institute of Biotechnology. Karwar, and Vision Group of Biotechnology
	Focus on Biotech applications: biocommerce, industry and R&D infrastructure conforming to international reference standards - pharmaceuticals, food and fermentation technology, biomedical engineering, and veterinary medicine	3 Parks foreseen at Ernakalulum, Idukki, Thiruvananthapuram in Kerala	Sponsored by Kerala Industrial Infrastructure Development Corporation
		Multidisciplinary Biotech Park involving government institutions and Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow	Central Institute of Medicinal & Aromatic Plants; National Botanical and Drug Research Institutes; and Industrial Toxicological Research Centre
	Development of pharmaceutical and healthcare production units; herbal/cosmetic and environment-friendly products; use of biosensors in bioprocessing of food items; and attraction of expatriate entrepreneurial expertise	Biotech Park in Kalamboli, Navi Mumbai (New Bombay) with focus on establishing a knowledge corridor between Bombay and Pune	Promoted by City and Industrial Corporation of Maharashtra (CIDCO)
		Industrial Biotechnology Park and All-Indian Bioinformatics Network , Pune to host information technology and biotechnology programmes; schools in the environmental sciences; and to develop contract research organizations (ROS) with good manufacturing practices	
	Potential for economic advancement	Ladwal Biotech Park. Punjab	Promoted by All-India Biotech Association

	30 *in situ* Medicinal Plant Conservation Areas	A Medicinal Plant Conservation Park at Pitchandikulam in Auroville Centre, Karnataka. Park museum houses a photo - reference exhibition of some 240 plants in the region; a seed propagation nursery to conserve endangered medicinal plants; a forest ethnomedicinal sanctuary of some 350 plants; a genebank; a herbal garden; and a disseminating facility linked with large-scale production in Karnataka, Kerala and Tamil Nadu	Programme launched in 1993 by Foundation for Revitalisation of Local Health Traditions
	Development of drugs from medicinal plants and herbs. Promotion of ethno-pharmacological research	Herbal Gene Bank at the Tropical Botanic Garden Research Institute, Thiruvananthapurnam	All-India ethnobiological project
Malaysia	Emerging Technologies-manufacture of medical and scientific instruments; advanced biomaterials; contract R&D services	Kulum Hi-tech Park. Kuala Lumpur	Sponsored by Kulum Technology Park Corporation Sdn Bhd
Nepal	Herbal and medicinal plant In Ayurvedic medicine	Medicinal plants cultivated in Doti, Shivpuri, Tistung, Tarakav and Urindavan herbal farms.	Research studies in co-operation with universities
Singapore	Pharma Zone for biotech and pharmaceutical companies	Agri-Bio Park --six agrotechnology parks being established to produce ornamental flowers and plants, food fish, ornamental fishes, and vegetables	Promoted by Institute of Molecular Agrobiology, Economic Development Board, and Primary Production Department
Sri Lanka	Inventorisation of plant genetic resources, medicinal plants and taxonomic data analyses	Establishment of a Women's Biotechnology Park foreseen	GEF/ World Bank project in framework of the Taxonomic Initiative
South Africa	Agricultural engineering, Plant production and animal wildlife healthcare	Porsequor Technopark, Pretoria	Maintained by Hatfield Experimental Farm and University of Pretoria
	Catalyse R & D interaction between biotech companies and universities in the Western Cape; natural products research	Technopark in Stellenbosch with focus on agriculture, food, aquaculture and marine products Conservation and use of east and southern Africa's medicinal plants	Maintained by Unistel Pvt.Ltd. and Stellenbosch University Natural Products Research Institute; WHO Centre for Drug Policy in the Western Cape

Table 6. Status of Biotechnology in some advancing and advanced developing countries.

Country	Features	Remarks	Reference
Brazil	*Rhizobium* Culture Collection at FEPAGRO/UFRGS MIRCEN laboratories functions as safety depositary Sugarcane EST Genome Project (SUCEST) schedule to end 2004, identifying around 50,000 genes networking with 38 Brazilian research institutions and Co-opersuccar Production of growth hormone in Brazilian corn –joint venture with universities of Campinas and Sao Paulo Development of (1) Papaya resistant to local strain of ring-spot virus, and (2) common beans resistant to golden mosaic virus	Development of national competence and capacity in intellectual property rights (IPRs)	Karanja et al (2000) FAPESP Genome Program (1999) Meidanis and Guimãres (2000) Sampaio (2000)
Burkina Faso	Improvement achieved in the household food security situation in the country in 1990 in comparison to that of the mid-1970s following political commitment	Development of mix of policy protocols concerning-soil conservation and water use	
China	Use of modern molecular technologies for varied biotech uses Development and use of the Desert Film Linen Technique (DFLT) with young rice plants in the Badanjlin Desert; technique under test by UNDP as preventive tool in arresting desertification National Committee monitors field testing of GMO crops Large-scale use of Blue-Green Algal fertilisers to obtain 7% rice yields increase and 30% decrease in use of chemical products Production in 2000 of super rice hybrid *Liang You Pei Jin*	Increase food production and improve product quality through clean technology use Development of national competence and capacity in IPRs More extensive use of genomics in agriculture	Zhang (2000)

Chile	Biotech enterprises BiosChile, Biogenetics, Bioforest and Biosonda have national and international profiles that focus on micropropagation of fruits and plant ornamentals production of diagnostic kits and vaccines for human and animal use research in genetic improvement if forest resources and pest and disease control	Development of knowledge-rich biotech base and biotech services responding to Chile and Latinamerican markets in Argentina, Colombia and Peru Development of national competence and capacity in biosafety policies and IPRs	(Nef, 1998); Gil et al (2001)
Costa Rica	National System of Conservation Areas Bioprospecting Program of National Biodiversity Institute (INBio) Rice Biotechnology Programme aiming at elimination of constraints in crop improvement and production Bioprospecting for bacterial genes for use in rice genomics Development of transgenic products	Expansion of bioprospecting activities covering bioresources and gene pools Development of knowledge-rich biotech base Development of national competence and capacity in biosafety policies and IPRs	Sittenfeld et al (2000)
Egypt	AGERI established in 1990 to bridge food gap and achieve self-reliance Success in development of transgenic potato, maize, faba beans, and tomato crops	Development of knowledge-rich biotech base Development of national competence and capacity in biosafety policies and IPRs	Madkour (2000**)**

India	Establishment of: National Biotechnology Board- 1982 Department of Biotechnology (DBT)- 1986 in Ministry of Science and Technology Micropropagation Technology Parks (New Delhi, Pune) for development of plant tissue culture industry National Bioinformatics Network with 10 nodal centres and 35 sub-nodal centres processing bioinformation National Plant Genome Research Centre, Jawarharlal Nehru University National Brain Research Centre National Bioscience Career Development Awards E-Biotech government web-site with details on technology services and commercial opportunities Research and training programmes involving States of Gujarat, Rajasthan, Madhya Pradesh, Orissa, West Bengal, Haryana, Punjab, Jammu & Kashmir, Mizoram, Andhra Pradesh and Uttar Pradesh with more than 5000 research publications, and 4000 postdoctoral students	Expansion of university-industry co-operation; development of a recombinant vaccine for tuberculosis and hepatitis; world's first IVF buffalo calf—*Pratham,* reared through embryo transfer at National Dairy Research Institute, Karnal; successful *White Revolution* with 80% of milk produced in small and rural farms Aquaculture and marine resource development Jai Vigyan mission with focus on development of genomic databases, vaccines, and diagnostics Special Awards for women scientists Bangalore, Delhi, and Bombay are considered to be the hotspots of biotechnology in India 59 MS, postdoctoral and MD training programmes either in progress or approved for immediate start	Sharma (2000) DBT (2001)
Iran	340 biotechnologists recognised in Iran; 46 institutes/centres engaged in biotechnologies *Razi* Institute designated as Reference Laboratory in Diagnostics National Research Centre for Genetic Engineering and Biotechnology established in 1988	Expand biotech expertise and excellence through newly established Iranian Society for Biotechnology and Iran Centre of Industrial Research and Development (IcIRAD) Widen impact of ongoing co-operation of Razi Vaccine and Serum Institute, Pasteur Institute of Iran with WHO Development of national competence and capacity in biotechnologies, biosafety policies and IPR guidelines;	Ghareyazi (2000) Shojaosadati (2000)

	1988 Covers wide range of research in biosciences, pharmacology, molecular biology, applied microbiology Produces growth hormone hepatitis B vaccine Iran Research Organization for Science and Technology establishes Biotechnology Centre in 1982 Active private sector *Rana Agro-Industry Corporation* produces tissue-culture date palm and banana *Cina Gene* company produces restriction enzymes, etc. University-industry collaboration	Combating salinity problems Hosts Persian Type Culture Collection Production of uniform and disease-free date-palm plants, cherry apple, bananas and sugarcane at the Agricultural Biotechnology Research Institute of Iran Pilot project (of Radha Co. and Tarbiat Modarres University) on bioleaching of copper from sulphide ores to industrial scale by 2002 Ministry of Mines and Metals project with Pharmacy Faculty, Teheran Medical school on recovery of gold and desulfurization of coal into university-industry joint ventures	
Jordan	Academic sector provides for R&D in various fields: natural products biotechnology; immunodiagnostics; bioreactor technology for production of bioenergy and biofuels; embryo transfer in animals; applied microbiology, BNF technology Active R&D industrial activities in immunobiologicals, tissue culture and developing of appropriate laboratory equipment	Develop academic competence and excellence for university-industry ventures in tissue culture ornamentals and products; monoclonal antibodies, single-cell-protein, enzyme production; molecular modelling; molecular genetics Establishment of a national biotechnological centre to drive and sustain on-going national efforts in diverse biotechnologies	Ajlouni and Malkawi (2000)
Kenya	MIRCEN builds on pioneering work in use of legume inoculants, and in market penetration in East Africa Use of tissue culture with banana, cassava, potato, and sugarcane crops Promotion of university-industry joint ventures	Development of knowledge-rich biotech base Quality control of nationally used legume inoculants ensured by MIRCEN laboratories Obtention of transgenic sweet potato resistant to feathery mottle virus Development of national competence and capacity in biosafety policies and IPRs	Ndiritu (2000) Karanja et al (2000)

Kuwait	Successful bioremediation of park soil in Ahmadi polluted with oil during Gulf war	Kuwait Institute for Scientific Research (KISR) pioneering research in arid land biotechnology and expanding profile as international centre of excellence in biotech research	
Mexico	GMO crop trials begin in 1988 Biosafety Committee issues monitoring guidelines for GMOs and risk assessment	Development of knowledge-rich biotech base Development of national competence and capacity in biosafety policies and IPRs	Alvarez-Morales (2000)
Philippines	Establishment of: National Institute of Molecular Biology and Biotechnology (BIOTECH) in 1980 at University of the Philippines (UP) ,Los Banos Three biotech centres, in 1995, in UP system at campuses in: Diliman (industrial biotechnology) Manila (human health) Visayas (marine biotechnology) National Research, Development and Extension Network; and 5 discipline –oriented networks	Deployment of biotechnology to boost agricultural productivity with minimal inputs Rural and public science education programmes to create public awareness; and attract private sector sponsors; counteract anti-biotech sentiment (GMOs); develop biosafety and IPR guidelines; engage in bio-prospecting and access to new technologies As of 1999, 250 top-level scientists engaged in high-level biotech R& D 13 biobased commodities: (*rice, corn, tubers, coconut, plantation crops, fibre crops, fruits/nuts, vegetables /spices, ornamentals, fisheries, aquaculture, livestock and poultry, and legumes*) *fishery post-harvest and marketing; soil and water resources; agricultural and fisheries engineering; postharvest food and nutrition, and social science policy and biotechnology*	de la Cruz (2000)

South Africa	Well advanced activities in agricultural sector Five-fold increase in protein content of sweet potatoes Obtention of transgenic tobacco and cotton varieties resistant to herbicides GMO Act of 1997 controls import of GM products; protects consumer and the environment Over 600 biotechnology projects in the medical and biosafety fields	Development of a national strategy in 2001, decreed by the Ministry of Arts, Culture, Science and Technology to establish a Bioethics Committee and a Biotechnology Advisory Council to monitor crop yields, production of vaccines, development of regional innovation centres and research laboratories; development of fungal resistant strawberries, maize and sorghum; insect-resistant sugarcane and virus-resistant potatoes 55 companies exist in the plant and medical biotechnologies	Njobe-Mbuli (2000)
Thailand	In 1991, establishment of National Centre for Genetic Engineering and Biotechnology (BIOTEC) with focus on R&D in transfer of technology and capacity-building Establishment of National Biosafety Committee in 1993 to provide guidance and monitor field trial evaluations of GMO crops In 1995, Cassava and Starch Technology program established; Production of new variety of tapioca—*Kasetsart 50* -Establishment of Rice Genome Project Thailand; conservation of high-quality fragrant rice cultivar *Khao-Hom Dawk-Mali* In 1999, establishment of Shrimp Biotechnology Program to sustain Thai shrimp farming and eradicate shrimp diseases	Need to improve crop diversification and yield; and postharvest conservation Use of biotech industries: food and animal feed; rubber ; and landscape and ornamental wood materials to establish Thailand as key export centre by 2002 Development of transgenic crops (papaya, pepper,) resistant to viral diseases Expansion of agricultural sector by 2.8% achieved in 1998 Commercial production of *Trichoderma* to control *Sclerotium rolfsii* Sacc., and *Chaetomium* to control *Phytophora* expansion of agricultural sector by 2.8% achieved in 1998	
UAE	Al Jarf area --transformed desert land with large date plantation Al Ajaban area --orchard plantation: mango, guava, and date palms	International Centre on Biosaline Agriculture pioneering research in saline agriculture and electronic communications network in arid land biotechnology; developing	DaSilva (2002)

		greening of coastlines	
	Ras Al-Khaimah poultry enterprise in Digdagga –vast egg production facility	Initiatives in greening of desert terrain	
	Mafraq wastewater facility provides irrigation waters for public gardens, parks		
Zimbabwe	Department of Agricultural Research and Specialist Services monitors development of hybrid maize	Kutsaga Research Station oversees tobacco breeding, pathology, etc	Chetsanga (2000)
	Establishment of Zimbabwe Biosafety Board in 1999 and promulgation of Zimbabwe Biosafety Regulations and IPR guidelines	Capacity-building in agricultural biotechnology and biosafety programmes	
	Introduction in 1980 of Master's Degree in University of Zimbabwe to promote biotech science education; Zimbabwe Biotechnology Training Programme funded by Netherlands, Sweden and Rockefeller Foundation	Essentially for drought-tolerant maize research	
	Establishment of Biotechnology Research Institute (BRI)		