TOWARD A REGIONAL AGENDA FOR AGROBIOTECHNOLOGY RESEARCH, INNOVATION AND INDUSTRY IN THE CARIBBEAN REGION

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CONTACTS FOR TASK FORCE PERSONNEL

IICA, Costa Rica
ADDRESS: IICA, P.O. Box 1318, 3 Herbert Street, St. Clair, Port of Spain, Trinidad
CONTACT PERSON: Aaron Parke, Enrique Alarcon
EMAIL: aparke@iicacarc.org, enrique.alarcon@iica.ac.cr

UWI, Mona campus, Jamaica
ADDRESS: Biotechnology Centre, University of the West Indies,
Mona, Kingston 7
CONTACT PERSON: Sylvia Mitchell
EMAIL: sylvia.mitchell@uwimona.edu.jm

CARDI, Barbados
ADDRESS: CARDI, P.O. Box 64, Cave Hill Campus, UWI, St. Michael, Barbados
CONTACT PERSON: Cyril Roberts
EMAIL: croberts@uwichill.edu.bb

IDIAF, Dominican Republic
ADDRESS: Calle Rafael Augusto Sancez No. 89, Ensance Evaristi Morales, Dominican Republic
CONTACT PERSON: Rufino Perez-Brennan, Daniel Duran Valverde
EMAIL: rperez@idiaf.org.do, indotec@codetel.net.do

Acknowledgement:

We acknowledge the input of Arlington Chesney, IICA, Director of Operations, Caribbean Region and Advisor to the Director General on Caribbean Affairs Arlington.Chesney@iica.ac.cr; Angel Castillo, IDIAF Director, Jorge Ardila - Technology and Innovation Director, IICA; Prof Ahmad profahmad@yahoo.com, Dr. W. McLaughlin wayne.mclaughlin@uwimona.edu.jm, Prof O'Garro logarro@uwichill.edu.bb, and Dr Umaharan pumaharan@fans.uwi.tt, UWI.

Copies of this discussion paper can be obtained from any of the task force personnel

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PREAMBLE

Technological innovation is a key factor for increasing competitiveness in agricultural systems world-wide. Improved agricultural yields have resulted from changes in plant genotype (by conventional breeding and genetic modification), and by improving cultural practices. In recent years, biotechnology in a broad sense (bio-pesticides, tissue culture, microbial-derived added-value products, marker assisted selection, genetic modifications and molecular biology technologies) has been the major factor in boosting agricultural productivity. Taking into account the large array of recent technologies that have been developed, more countries should be preparing to take full advantage of the benefits that could be derived from biotechnology. Successful countries in the assembling and implementation of a strong science and technology agenda with a biotechnology focus have understood that more creative and efficient means have to be identified to face problems such as food insecurity, natural resource degradation and devastating diseases. These countries include USA, Canada, Australia (developed countries) Argentina, and China (developing countries) (see Figure 1). As a result, these countries are today reaping the benefits. China and Argentina are good examples to validate the fact that biotechnology can be implemented in developing countries as well. Other developing countries, which have lately put biotechnology in the center of their efforts towards development, are India, Chile, Brazil and Cuba. Brazil is a case study of how a developing country can reap the benefits of applying technology to agriculture. While Brazil has applied conventional technologies to agriculture they have also developed strong capacity in cutting-edge biotechnologies applied to production systems along the agri-food chain.

The Caribbean region consists of 25 island states and four associated continental countries[1] most of which have small populations (21 with populations less than 0.5 million) thus limiting the degree to which these countries can take advantage of economies of scale. The three largest countries (Cuba, Haiti, Dominican Republic) had 69% of the region's total population of 38 million in 2002. Most of the countries in the Caribbean can be considered as developing as they have low GDP per capita (Table 1). Agriculture provides 1-30% of GDP in the region (Table 1) but also impacts on biodiversity and tourism and therefore has many ripple effects. Traditionally, the base of these economies has been dependent on the export of tropical agricultural crops, but in the last decades the tourist industry has become increasingly dominant. This fact poses the challenge of coping with the forthcoming needs in terms of food security and food safety, and a diverse, attractive environmental offer. If it is a national vision or strategy to maintain this kind of economy in the track of competitiveness, knowing the enormous potential contribution of agro-biotechnology to face this challenge, these countries are obviously compelled to have a long-term Agenda for the application of agricultural biotechnology in the region. Nevertheless, the Caribbean countries, with the exception of Cuba and Puerto Rico, have yet to understand the paramount importance of biotechnology, as reflected in the lack of investment in national R&D capacities. Compared to other regions, the technological institutional frameworks for agricultural research and low levels of R&D have severely disadvantaged Caribbean agriculture. Agricultural research intensities range from 0-8.3% (see Table 2 in the appendix) but only a small portion of this is in agro-biotechnology. The geopolitical fragmentation of the region has placed a major constraint on agricultural research and development. A shared regional vision for the use of agricultural biotechnology as a strategy therefore needs to be pursued urgently.

[1] Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Cuba, Dominica, Dominican Republic, French Guiana, Grenada, Guadeloupe, Guyana, Haiti, Jamaica, Martinique, Montserrat, Netherlands Antilles, Puerto Rico, St Kitts-Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos, and the US Virgin Islands.

Biotechnology has many benefits to offer Caribbean agriculture, especially to take full advantage of its rich biodiversity. While there have been numerous advancements in biotechnology in several Caribbean island states, there is as yet no Caribbean-wide agenda as it relates to agricultural biotechnology. Despite numerous attempts, a mechanism to develop agriculture using the tools of biotechnology on a regional scale has not been found. Many reviews of the region point to the low levels of innovation. Recently, however, there have been promising biotechnology innovations developing in many countries in the Caribbean including Cuba, Jamaica, Barbados, Trinidad and Tobago, and the Dominican Republic. Several other countries in the Caribbean are producing reasonable amounts of tissue culture planting material (Grenada, St. Lucia, St. Vincent, Barbados, Suriname, Trinidad and Tobago) but none of these labs are privately owned. Acquisition of biotechnology skills, development of infrastructure and a suitable regulatory environment to sustain such technology and encourage innovation and commercialization is paramount. Plant biotechnology applications must respond to increasing demands in terms of competitiveness, food security, socio-economic development to promote the conservation, diversification and sustainable use of plant genetic resources as basic inputs for the future agricultural pursuits of the Caribbean. With support, both by facilitating collaboration and finances, agricultural biotechnology has the potential to transform the Caribbean from a low profit primary producer to a sophisticated producer of a diversity of profitable crops and value-added products thus leading to its increased competitiveness and sustained development.

While it is largely recognized that most advances in biotechnology during the last ten years (1994 - 2004) has been done mainly on crops and animals of interest to developed countries (template crops), an obvious trend is in surge now, towards investing more on the genetic resources of tropical biotechnology. Great examples are the exploration of tropical medicinal plants and microorganisms, agricultural crops like rice and high biomass–producing crops such as sugarcane. This trend points toward a very promising future for the Caribbean, as the region could become a suitable supplier of elaborated raw material for the pharmaceutical industry and/or an effective supplier for the clean energy producing industry. To be part of this future, the region has to “grow in biotechnology”. The best and first efforts should be oriented towards capacity building and gain synergy as a region for a common agenda.

Consequently, it is important to recognize the urgency of a regional biotechnology agenda. With a global economy and the need for harmonization - the development of a regional strategy is very important. Joint efforts can also assist with developing economies of scale. Thus, national capacities should fit into a regional platform thus facilitating growth and trade. At the same time as economic growth is promoted through the application of agrobiotechnology, the sustained use of biodiversity and application of biosafety principles needs to be taken into account.

There have been previous attempts to encourage biotechnology networking in the region but they have not been sustained. Recently (March 16-18, 2004), a group of regional biotechnologists from both the Spanish-speaking and English-speaking Caribbean met in the Dominican Republic to analyze previous attempts at developing a regional agenda for agrobiotechnology[2]. It was the consensus of this meeting that this process should begin with the establishment of a Consultative Group of Agricultural Biotechnology in the Caribbean (CGABC), as part of strategy to gain strength as a region to cope with the challenges entailed in setting the ambient to intelligently exploit biotechnology in the region. The CGABC, as a technical and scientific support source for Caribbean countries would help in outlining strategies and a regional agenda. A regional agenda would, after a consultative process with regional and extra-regional biotechnologists and other counterparts, be endorsed by regional governments and be used to develop, and more widely utilize, the tools of agricultural biotechnology in the Caribbean.

[2] Mitchell S.A. (2004) Towards a Caribbean Regional Agro-biotechnology Strategy and Action Plan. Aide Memoir of the preparatory meet ing for the reactivation of the Caribbean Biotechnology Group: ‘Agro-biotechnology in the Caribbean: Present and Future’. March 16-19th 22 pages (summary document available from IICA).

The CGABC would act to support the regional development of agricultural biotechnology by developing projects, analyzing world-wide biotechnology developments, informing governments and civil society of the advantages and disadvantages of biotechnology, providing training workshops and by facilitating interactions between regional biotechnologists, serving as a scientific and technological antenna as well as a means of knowledge dissemination through scientific publications. The outline of the regional agenda and the CGABC is given in this document.

1.0 EXECUTIVE SUMMARY

In this document, is discussed a biotechnology agenda for the Caribbean, in terms of vision, policy frameworks, regional strategy and initiatives. Besides, it is examined the scope, opportunities and challenges for this sector in the region.

2.0 BACKGROUND AND THE NEED FOR A REGIONAL AGENDA

Biotechnology is currently experiencing a very strong surge in the Caribbean with a growing awareness among scientists, entrepreneurs and bureaucrats alike, of its potential for enhancing agricultural growth and productivity. Agrobiotechnology represents a viable and promising tool for resolving serious problems affecting the development of agriculture, provision of food, preservation of the environment and the development of value-added products.

In countries with similar characteristics to the Caribbean like China and India, biotechnology is nowadays being heralded as their new face. From DNA microarray to proteomics, from genomes to drugs, and stem cells to tissue engineering, biotechnology has a wide array of applications that have been seen by these countries as a catalyst for economic growth, social welfare, and industrial development.

Although there have been collective and individual efforts by countries and organizations for the advancement of agro-biotechnology in the region, there is at this moment no holistic strategy to guide its application or adoption as a developmental tool in the Caribbean. Thus, to leverage biotechnology as the growth engine in the Caribbean, a lot has to be done regarding emerging trends, especially regulatory challenges and the setting of a viable platform to boost biotechnology industry in the region.

Up to today, most of the agricultural biotechnology in the Caribbean region has been done in Cuba, Puerto Rico, at the University of the West Indies (UWI) on its three campuses in Jamaica, Barbados and Trinidad and Tobago, and by the Caribbean Agriculture Research and Development Institute (CARDI), which has offices in many of the Caribbean island states. Both UWI and CARDI have a regional focus. UWI trains undergraduate and graduate students in a range of skills applicable to agricultural biotechnology including microbiology, biochemistry, tissue culture, plant improvement and molecular biology. Undergraduates in biotechnology-related subjects are produced each year throughout the region by regional universities. There are many biotechnology research groups at UWI actively engaged with agriculturally-related projects (see Table 3 and 4). Although UWI has a growing capacity to carry out agrobiotechnology research it is still seriously underfunded and requires significant investment so that innovations can be developed and transferred to the productive sector. CARDI has a more traditional agricultural focus but has utilized and is interested in further investment in biotechnology for regional advancement (see Table 5).

The existence of a good range of organizations and networks in biotechnology in Latin America and the Caribbean can boost the collective effort (see Table 6). Of note is PROCICARIBE, the Caribbean network that covers many aspects of agricultural science and technology and which serves as an instrument in the implementation of strategies for the coordination of research programs in agriculture at the regional level and also at the individual country level. The role of PROCICARIBE as an important linkage between regional and international institutions needs strengthening.

Of direct relevance to the application of Agro-biotechnology are CARINET (Caribbean Biosystematics Network) and CAPGERNET (Caribbean Network for Plant Genetic Resources) that can contribute to the sustainable development of the genetic resources of the region and their rational utilization. There exist also, other networks including CIMPNET, for the integrated management of pests.

One step towards the systematic application of biotechnology in the region was the establishment of a Caribbean Biotechnology Network (CBN), within the framework of UNESCO's global network of Microbial Resources Centres (MIRCENs)[3]. It was set up in 1988. To date, there is only one MIRCEN

[3] DaSilva EJ and M Taylor (1998) Island Communities and Biotechnology. Electronic Journal of Biotechnology Vol 1 No. 1, Issue of April 15, 1-10/

in the Caribbean[4]. The CBN began a newsletter and based on results from distributed questionnaires, produced a CBN Directory in 1991[5]. This Directory provides a listing of persons (and their institutions) in the Caribbean region who were in some way involved in biotechnology in 1991. At that time, there were 57 scientists listed who were in some way involved in biotechnology. No further directories have been produced. The Third Caribbean Biotechnology Conference was held in Jamaica in 1992, and the Fourth in Trinidad and Tobago in 1994.

Another step forward was a workshop held in Trinidad and Tobago in 1998, 'Perspectives for Biotechnology in the Caribbean', which 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
- Antisera and diagnostics
- Sugar industry fermentations
- Embryo transfer technology

Another initiative is UNU/BIOLAC[6]. The United Nations University (UNU) Programme for Biotechnology in Latin America and the Caribbean (BIOLAC) was established in January 1988 in Caracas, Venezuela. The Programme promotes the development of biotechnology in the Latin American and Caribbean region. Its overall objective is to promote the development of biotechnology in the region through academic exchanges by awarding fellowships for research and advanced training in selected leading biotechnology laboratories within the region and by organizing short training courses. To date, the Caribbean has not taken advantage of this initiative, except for Cuba. Of the 127 fellowships given between 1988 and 1996 by UNU/BIOLAC, from the Caribbean there were only 21 fellows from Cuba and one each from the Dominican Republic and Barbados. The activities of the Programme are focused on nine specialized priority areas as recommended by the UNU/BIOLAC Scientific Advisory Committee (SAC):

- Agricultural biotechnology
- Bioinformatics
- Genomics
- Industrial microbiology
- Industrial relations
- Manufacturing of advanced biotechnological products
- Medical biotechnology
- Molecular biology
- Molecular pathology

The Regional Biotechnology Programme for Latin America and the Caribbean was set up by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1983[7]. The rationale of the regional programme was that:

- scientific and technological integration among the countries of the region should be fostered
- co-operation among these countries should increase substantially
- research and development should be linked to the productive sector
- available resources should be concentrated on a limited number of projects of high social and economic impact.

[4] Dr J. Duncan, Microbial Biotechnology MIRCEN, Caribbean Industrial Research Institute, Tunapuna, Trinidad and Tobago. Tel: (1-809) 662 71 61. Fax: (1-809) 662 71 77.
[5] CBN Directory 1991 UNDP/UNESCO RLA/87/024
[6] Daza C (1996) Scientific research and training in biotechnology in Latin America and the Caribbean: the UNU/BIOLAC experience. Electronic Journal of Biotechnology 1(2), Issue of August 15, 1996. pg 1-9
[7] http://www.redbio.org/html/Content.PDF, http://www.redbio.org/who/index.asp

The five-year (1987-1991) Regional Biotechnology Prgramme for Latin America and the Caribbean was implemented by UNIDO (United Nation Industrial Development Organization) and UNESCO. It involved 13 countries of which one (Cuba) was in the Caribbean. The input of the rest of the Caribbean has been very minimal.

During the planning meeting on Appropriate Biotechnology for Crop Production in 1989, by the FAO Regional Office for Latin America and the Caribbean, a recommendation was addressed to the FAO to examine the feasibility of setting up a technical co-operation network among plant biotechnology laboratories. It was recommended that the program be established for the development of plant biotechnologies – to provide a directory of human resources, an inventory of plant biotechnology laboratories and an analysis of trends in terms of priorities, crop species and technologies. An analysis of biotechnology in the region revealed enough equipment and infrastructure but a lack of training in advanced plant biotechnologies, molecular biology, cell and tissue culture applied to genetic improvement of crop species, and methods for the diagnosis of food-crop diseases; a limited operating budget; and a vacuum caused by the lack of a technical co-operation network on information and research. To fill this void, in 1990, under the sponsorship of FAO, the Technical Co-operation Network on Plant Biotechnology (REDBIO) was set up. By early 2000, the REDBIO included more than 549 laboratories in 32 countries from Latin America and the Caribbean; 83% of these laboratories had <10 researchers and technical staff and only 72% of this total had a minimum of three post-graduate researchers.

An important initiative to be highlighted in the regional effort to promote the development of biotechnology in the Caribbean was the establishment of a Caribbean Node of REDBIO (Caribbean REDBIO) with resources from the European Union Caribbean Agriculture and Fisheries Program (CAFP) project. Through this initiative, representatives from some 15 countries of the Cariforum region including the Dominican Republic met in 1999 to discuss and agree on a realistic regional strategy and policy for the development of agrobiotechnology in the Caribbean (CEDAF 1999). This project had as its main purpose the identification of collaborative and cooperative strategies to enhance information exchange and bio-technical knowledge in the Caribbean. At that meeting, attended by over 40 regional biotechnologists, it was voted that the best of all available option to create a Caribbean Biotechnology Network was to create a Caribbean component of REDBIO.

It was expected that the CAFP effort would have resulted in a strengthened Caribbean Biotechnology Network as the regional node of the Latin American and Caribbean REDBIO/FAO. While the network was launched in 2000 there has been no follow up activity as the foundation was too weak. Perhaps, the major constraint that limited the advancement and impact of REDBIO Caribbean was the lack of a cohesive group or a task force (support structure) within the region that would undertake actions of the outlined agenda that resulted from the various meetings and workshops. Also, a more decisive support from the REDBIO parent would have been helpful. This means that, in order for a regional agenda on biotechnology to move forward at the long run, the establishment and implementation of the CGABC might prove critical. Likewise, a strategy to gain support both from regional governments and cooperation agencies is also essential.

None of these initiatives, so far, have resulted in a sustained and working Caribbean Biotechnology regional initiative so while biotechnology is being utilized in the Caribbean, its full potential is far from being tapped. At a meeting of regional biotechnologists in March 2004 in the Dominican Republic through the sponsorship of IICA and IDIAF, it was felt that more than a network will be needed and that measures would need to be taken to ensure the mistakes of the past are not repeated.

Such an agro-biotechnology thrust should:

a. Provide information on what is happening in the Caribbean in biotechnology, on an annual basis, thus, a scientific meeting within the region annually as a forum to discuss biotech advancement and prospective should be part of a regional strategy;
b. be a repository of innovative information related to agro-biotechnology that is developed within the region;

c. be able to analyze and repackage biotechnology related information from without the region for the region, thus, dissemination means such as journal and bulletins, should be part of a regional strategy both physical and electronic;
d. have an advisory/consultative capacity;
e. reflect the collective wisdom of its stakeholders;
f. have technical and scientific backstopping;
g. have the ability to identify common needs, priorities and activities;
h. have funds for projects;
i. be able to network biotechnologists of the region together;
j. facilitate workshops and other capacity building exercises;
k. facilitate the interaction of regional biotechnologists with those outside the Caribbean (North-South and South-South opportunities);
l. be a conduit through which information of importance to agriculture and biotechnology can flow;
m. be endorsed by regional governments – have a political mandate;
n. have legal status to work in a regional capacity to access regional opportunities;
o. be self-fulfilling by bringing benefit to regional agro-biotechnologists and to the island states of which they are a part;
p. have the capacity to formulate research and training projects based on regional/ national problems and or opportunities.

The Caribbean region needs to make a significant investment in biotechnology in order to increase the competitiveness of the region's agricultural pursuits. To maximize this investment the region needs to decide its priorities and to determine how to meet the market requirements of certification in a coherent manner. It, therefore, has to decide what to do with biotechnology and how to harness its potential for the better good of the Caribbean people.

3.0 FOUNDATION

3.1 Agricultural challenges in the Caribbean in the context of the region's integration and globalization

Agriculture is important to the Caribbean region[8]. For several countries, it is the lifeline, supplying much needed foreign exchange, employing a large percentage of the labor force, and having much ripple effects in the economy. A limited number of export-destined plantation crops, such as sugarcane, banana, coconut and cocoa, have been the mainstay of the agricultural systems since colonial times, and have made many Caribbean countries vulnerable to world price fluctuations. Bananas still dominate 90% of the agricultural sector of Dominica and St. Lucia. In 1996, ~40% of Belize's hard currency earnings were from sugar. In 1997, export earnings for sugar and sugar byproducts accounted for US$35 million in T&T and US$102 million in Jamaica. In Guyana, in 1998, export earning for rice was ~ US$73 million – 80% of which was going to Europe. Cheaper imports have destroyed the rice industry in T&T. These large-scale crops utilize most of the flat land of the Caribbean and provide valuable foreign exchange. Unfortunately, yields are low and prices for these commodity crops are low and dropping. Furthermore, these crops do not satisfy the diverse and changing demand of the flourishing tourism industry. On the other hand, non-traditional exports (such as avocado, pineapple, mango, yam) have increased in area and profitability.

Despite the importance of agricultural production to the region, the region's agricultural sector currently faces the following challenges:

a) Reorganization of the sector in response to globalization;
b) Expiration of preferential market agreements on traditional agricultural commodities eg sugar, banana and rice;
c) A reduction in public funds for agricultural research and development (R&D);
d) Ensuring that R&D efforts are designed to boost competitiveness and increase profitability of the regional agricultural sector;
e) Co-ordination of agricultural R&D efforts nationally and regionally with links to international organizations;
f) Developing an information system that can assist the region to access, generate and utilize new and appropriate technologies;
g) Establishment of regulatory frameworks that would render credibility in agro product trade, by providing traceability and biosafety;
h) Increasing the critical mass of scientists to utilize regional and national R&D installed capacity;
i) Obtaining "State commitment" to support R&D.

Agricultural R&D is now characterized in the Caribbean by a decrease in grant funds and local funds due to fiscal pressure on governments and businesses. The markets of the world are increasingly demanding accountability. This is leading to increasing certification requirements for good agricultural practices, manufacturing practices, traceability, level of care of workers etc. This also increases the cost of doing business.

Most of the farms in the region are small. The challenge of developing sustainable agricultural systems on the small parcels of flat and slopping lands on the Caribbean islands are many. Recent developments in biotechnology such as tissue culture and genetic engineering, coupled with the inventiveness of the Caribbean people can help to make the region's agriculture more competitive and thus ease the region's integration into the global economy. However, the research teams in universities, agricultural institutions and ministries of agriculture are poorly connected and/or integrated, have a high dispersion of facilities and qualified labor force. The challenge will be, to make

[8] This section draws on the PROCICARIBE document 'Integrating Agricultural R&D efforts in the next millenium: A strategic plan for PROCICARIBE 2000-2005, written by PROCICARIBE-CARDI.

biotechnology to work for us, in spite of these difficulties. Facilities and research numbers are still below critical mass for biotechnology to have the impact it should on agriculture in the region.

It is important to analyze what is happening in other regions of the world and recognize that there are ways of accelerating the development of biotechnology in the Caribbean. For example, Bio-business is a new area that could render important benefits to the Caribbean. Bioparks are becoming a reality in many countries. Bioparks are different from the free-zone model in that besides leaving large economic benefits where they are established, they also provide significant technological and scientific spillover. Biopark clusters could become a very effective technological and scientific platform for the region.

The United State of America and Europe hold 90% of the global benefits of biotechnology and house most of the 4,300 biotech companies of the world, inventoried up to the end of 2003.

New trade arrangements and geographical location of the Caribbean region provide comparative advantage to capture part of these profits through the establishment of cluster-type operation centers in the Caribbean to house a good number of these companies. Meanwhile, other regions are reaping the profit. Japan alone employs 70,000 people in biobusiness. For 2010, Japanese expect to employ 1 million people in biotech related business. Singapore is expecting to generate 7,000 million USD only through the Biopolis biopark. BIOPOLIS is a 1.7 billion investment biopark.

While minimum requirements and national/regional commitments are necessary to make it possible for the development of Caribbean bioparks, it is certain that a large number of US and European biotech companies would operate in Caribbean bioparks. Some of the requirements include government commitment, national/ regional private sector support and involvement of academic entities.

3.2 Wealth of biodiversity and genetic resources of the Caribbean

The Caribbean[9] is a biodiversity 'hotspot', rich in endemic flora and diverse plant genetic resources. Hotspots have been defined as regions that harbor a great diversity of endemic species and, at the same time, have been significantly impacted and altered by human activities [10]. The Caribbean is home to 2.3% (7,000) of the world's endemic plant species and 2.9% (779) of endemic vertebrate species, on only 0.15% of the Earth's surface. These figures are all underestimations, as biodiversity studies are urgently needed. Only 10% of the original vegetation is left; most of the original vegetation was cleared during the colonization period for agriculture purposes, and more recently for housing, industrial and tourism endeavors.

The endemic and indigenous biodiversity of the Caribbean is the raw material on which biotechnology depends. As well as endemic plants and animals, the Caribbean has a lot of land races and variations among its agricultural and wild plants. An example of this diversity is seen in the hot peppers. The breeding potential of these crops is only now being explored. There are also crops that are unique to the Caribbean such as pimento or have been made into a crop within the Caribbean such as ackee. Tropical forest and wood species like the mahogany, green eben tree, real palm tree and the Antillean pines are unique and have great importance in eco-tourism. All these represent a source of genetic resources that have barely been tapped. Lack of surveys and inventories of plant species means the biodiversity of the Caribbean has not yet even been characterized, let alone utilized.

The number of landraces in most countries of the Caribbean is on the decline due to two major reasons: (i) the introduction of high-yielding, improved varieties and hybrids that has displaced traditional varieties and (ii) as the number of small farmers decreases so does the number of custodians

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[9] CI (2004b) Biodiversity Hotspots. Caribbean http://www.biodiversityhotspots.org/xp/Hotspots/caribbean/
[10] CI (2004a) Biodiversity Hotspots. What are hotspots? http://www.biodiversityhotspots.org/xp/Hotspots/hotspotsScience/

of existing landraces[11]. Much of the indigenous vegetation of the Caribbean islands was cleared by early colonizers and others are presently much degraded. The Caribbean Islands are an important centre of diversity of many cultivated plants. Some of the plant species that are indigenous or have developed important genetic diversity in the Caribbean include the following:

- Roots and tubers: *Ipomoea batatas* (sweet potato), *Manihot esculenta* (cassava), *Dioscorea trifida* (yam), *Calathea allouia, Canna edulis, Maranta arundinacea* (arrowroot) and *Xanthosoma sagittifolium* (eddoe);
- Cereals: *Zea mays* (corn);
- Legumes: *Phaseolus lunatus, Phaseolus vulgaris* (red peas), *Vigna unguiculata, Vigna sesquipedalis* and *Cajanus cajan* (gungo peas);
- Oil crops: *Arachis hypogea* (peanuts);
- Palm species: *Acronomia spp.* and *Prestoea montana*;
- Species for industrial use: *Crescentia cujete, Gossipium barbadense* (cotton) and *Manilkara bidentata*;
- Aromatic, stimulant and spice species: *Bixa orellana, Capsicum spp.* (peppers), *Colubrina reclinata, Nicotina tabacum* (tobacco), *Pimenta dioica* (pimento), *Polygala spp., Theobroma cacao* (cacao) and *Vanilla pleei* (vanilla);
- Pasture species: *Axonopus affinis, Bothriochloa pertusa, Panicum maximum, Paspalum spp., Aeschynomene spp., Desmodium spp., Leucaena spp., Macroptilium spp.* and *Stylosanthes hamata*;
- Fruit species: *Spondias spp., Annona spp., Carica papaya* (papaya), *Mammea americana, Persea americana* (avocado pear), *Hymenaea courbaril, Inga edulis, Malpighia punicifolia, Byrsonima spp., Eugenia spp., Psidum guajava* (guava), *Coccoloba uvifera, Genipa americana, Melicocca bijuga* (guinep), *Talisia olivaeformis, Calocarpum mammosum, Chrysophyllum cainito, Manilkara spp., Pouteria spp, Monstera deliciosa, Opuntia ficus-indica, Cucurbita spp., Passiflora spp.,* and *Solanum spp.*
- Timber species: *Avicennia germinans, Laguncularia racemosa, Rhizophora mangle* (mangrove), *Drypetes spp., Hymenaea courbaril, Mastichodendron foetidussum, Sloanea caribea* and *Tabebuia pallida*;
- Ornamentals: such as *Alloplectus cristatus, Petrea kohautiana, Tecoma stans, Byrsonima spicata, Lobelia conglobata, Charianthus alpinus, Macgravia spp., Helicona spp., spp of* orchids, cactaceae, ferns, aroids and palms;
- Medicinal plant species: *Aristolochia trilobata, Capraria biflora, Eupatorium triplinerve, Exostema caribeae, Justicia pectoralis, Richeria grandis, Cassia spp, Sauvagesia erecta* and many more[10].

3.3 Development of biotechnology

For convenience, biotechnology can be divided into three main areas – those concerned with the growth of micro-organisms (microbial biotechnology), those techniques involved with the *in vitro* growth of plants or animals (tissue culture/cloning), and those techniques resulting in improved organisms – whether plant or animals (genetic engineering).

Agricultural biotechnology has different levels of implementation and development according to its degree of complexity, infrastructure costs and investment[10]. The first level includes technologies of low complexity and cost like handmade and semi-industrial production of biological products: like bio-inoculants, composting, production of pest antagonist and pest predators, production of bio-pesticides, small-scale production of value-added products from herbs, spices and medicinal plants and hydroponics. The transfer of these simple technologies to small producers has proven feasible and can

[11] FAO (1997) FAO International Technical Conference on Plant Genetic Resources 'Conservation and Sustainable Utilization of Plant Genetic Resources in the Caribbean' Sub-Regional Synthesis Report. Annex 1 of the Report of the Sub-Regional Preparatory Meeting for Central America, Mexico and the Caribbean, San Jose, Costa Rica, 21-24 August 1995 http://icppgr.ecoport.org/pdf/amerce1e.pdf

offer remarkable results quickly. Products made by fermentation were early examples of the use of a biotechnology: wines, bread, pickles and cheese making and for the Caribbean, rum making. The use of microbes to make industrial products is very much underutilized in the Caribbean with only Cuba and Puerto Rico making use of this biotechnology.

The second level comprises the application of cell and tissue culture techniques, cell culture for production of secondary metabolites, disease diagnostic systems based on polyclonal antibodies and other technologies with medium complexity. Tissue culture is utilized for the production of disease-indexed planting material via micropropagation and somatic embryogenesis. This stage can also include investments to implement semi-industrial production of biological products. The results of these technologies can be seen in the medium term (3-5 years) but depend on efficient organization for extending the results from the laboratory to the field and transferring the biotechnology to businesses. Tissue culture was developed in the 1950s and became popular in the 1960s. In 1960 Morel produced four million genetically identical plants from one orchid bud in one year. In the Caribbean there are small tissue culture laboratories in most countries, which are producing reasonable amounts of planting material (Table 5). In Jamaica (limited to orchids), Dominican Republic and Suriname there are privately run tissue culture labs.

The third level considers the use of molecular biology, genetic engineering, large-scale industrial production of biological products and complex microbial, plant cell and tissue culture techniques such as liquid bioreactors. Before the 1980's, plant biotechnology comprised only a few applications of tissue culture, recombinant DNA technology and monoclonal antibodies[12]. Now, transformation and marker-aided selection and breeding comprise only a few of the applications of biotechnology to crop improvement. Within the last 100 years the world has seen genetics become a scientific discipline (1900s), DNA being found as the hereditary material (1944), the elucidation of the double helix structure of DNA (1953), cracking of the genetic code (1996), the ability to isolate genes (1973) and the application of DNA recombinant techniques (1980 onwards). This level is characterized by its complexity and high cost of research and development. The short-term impact of this advanced biotechnology may be limited because, as in any novel technology, it needs a starting phase corresponding to the innovation of its own research methods, analytical inputs and equipment. To create such a condition it is compulsory to build a framework of institutional support by public and private investment sectors[11]. There are ways, however, to increase the short-term impact while investing for the long term.

The first transgenic plant, a tobacco accession resistant to an antibiotic, was reported in 1983. Transgenic crops with herbicide, virus or insect resistance, delayed fruit ripening, male sterility and new chemical composition were released in the market in the 1990s. From 1980 to 1992, worldwide sales of biotechnology-derived products grew by US $ 6 billion and by the end of the twentieth century, sales in the USA alone was ~ US $ 50 billion. In 1996, there were about 3 million hectares of transgenic crops in the world, and by 1998, there were 34 million hectares (in North America, Argentina, China and South America). In 1996 in the United States, 15 novel genetically modified plant products existed in the market whose initial sales totaled about 380 million dollars[13]. In 1998, there were 1,300 biotech companies in USA alone with a total of nearly US $ 13 million in annual revenue and more than 100,000 employees. In addition, there are 400 biotechnology related companies in Europe. In 2002, the global area under cultivation of GM crops was 58.7 million hectares with a market value of around US $4.25 billion[14]. Of this, 39 million hectares was in the USA and included GM soybean, corn, cotton, canola, tomato, squash, potato, chicory, papaya, rice and flax. In the

[12] Ortiz R (1998) Critical role of plant biotechnology for the genetic improvement of food crops: perspectives for the next millennium. Electronic Journal of Biotechnology 1(3), Issue of August 15, 152-159.

[13] Izquierdo J and GA de la Riva (2000) Plant biotechnology and food security in Latin America and the Caribbean. Electronic Journal of Biotechnology 3(1), Issue of April 15, 1-8.

[14] Biotechnology Strategy for Agriculture, Food and Fibre, Australian Government, Department of Agriculture, Fisheries and Forestry, 2003 www.affa.gov.au/biotech

Caribbean, biotechnology in the form of transgenic plants and molecular-marker assisted breeding is increasingly being used to produce improved planting stocks.

Biotechnology involves a wide variety of biological manipulations such as cell and tissue culture, embryo transplantation, vaccine production, transfer of DNA across sexual barriers, fermentation and various ways of degrading complex macromolecules found in biomass into simpler molecules to serve as sources of food, energy and other useful products. Some of these techniques such as fermentation have evolved over centuries of use by man. However, modern biotechnology is rooted in recombinant DNA technology, which is the outgrowth of advances made in the past four decades in biochemistry, molecular biology, immunology and related disciplines. Although modern biotechnology involves the application of research at the cutting edge of basic sciences, it is a group of technologies that are appropriate for solving the problems of nations at various stages of development [15].

Technology developments include:

- Advancements in fermentation for the production of value-added products from agricultural crops such as xanthum gum from molasses;
- Bioprospecting and access to biological resources to develop new drugs and industrial biotechnology, including novel traits in industrial crops;
- Use of green feedstock for the bioenergy and industrial chemical sectors (biotransformation eg ethanol from sugar cane);
- Use of biotechnology to control weeds and pests and restore landscapes (biopesticides, bioinoculants, biofertilizers);
- Application of tissue culture methods / hydroponics to tropical crops;
- Embryonic Transfer Technology;
- Development of livestock cloning technologies;
- Marker-assisted breeding of plants and animals;
- DNA fingerprinting of plant varieties;
- Functional genomics to understand gene function and regulation in plants and animals;
- Development of genetically engineered crops and plants including regeneration techniques;
- Development of cropping alternatives in lands degraded by erosion and desertification or by careless agricultural use;
- RNA interference technology in plants and animals;
- Plant disease diagnosis and development of diagnostic kits;
- Development of agronomic strategies/biosafety frameworks to manage genetically modified crops;
- Use of bioinformatics to generate and mine new information from large data sets including information on genomic structure and its diversity[10].

Wise use of biotechnology in the agricultural sector can lead to conservation of biodiversity within the farm system. By increasing yields within the agricultural sector, more lands can be protected within undisturbed and forested areas. Wise application of marine biotechnology can also lead to protection of marine biodiversity. Incorporation of new crops into the farming sector (such as medicinal plants) via plant biotechnology (tissue culture etc) will lead to diversification and agricultural development. Methods to enhance soils and decrease the effect of soil diseases (bioinoculants, biopesticides), and the provision of clean and improved planting material will increase productivity and therefore the competitiveness of Caribbean agriculture. The use of microbial biotechnology can increase value of crops by the production of new and useful value-added products such as ethanol from sugar cane and xanthum gum from molasses.

Increasingly, biotechnology is being applied to agriculture as part of a system approach. For example, a pest problem might equally be addressed through conventional plant breeding, with assistance of

[15] UNU Program for Biotechnology in Latin America and the Caribbean
http://www.unu.edu/capacitybuilding/Pg_biolac/pg.html

molecular markers, through a transgenic approach, by the use of bio-pesticides, through an integrated crop management (ICM) approach or by any combination of these[10].

3.4 Consumer acceptance

Acceptance by public of products derived from microbial biotechnology especially for medical applications or tissue culture for rapid propagation of planting material has traditionally been faster than for genetically modified foods. Acceptance by the market has been faster in the Americas than in Europe. The speed of adopting of existing and new biotechnologies will depend ultimately on the requirements of the market. At present there are few agreed international standards that specifically address GMO health and environmental safety assessment or labeling requirements although it is actively being pursued.

3.5 Regulatory Framework

Biotechnology enables the rapid multiplication of organisms (by fermentation or tissue culture) above that encountered in nature. Biotechnology includes methods that allow for transfer of genetic material, which by nature could not be transferred, resulting in genetically modified organisms, or GMOs. These new methods, to be safe, need to be monitored so biosafety regulations have been established.

Biosafety is a term used to describe efforts to reduce or eliminate the potential risks resulting from biotechnology.

There are multilateral environmental agreements concerning the establishment and use of biosafety regulations and regulatory framework. A supplemental agreement to the Convention on Biological Diversity known as the *Cartagena Protocol on Biosafety* was adopted on January 29th, 2000. The Protocol seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology. It establishes an advanced informed agreement (AIA) procedure for ensuring that countries are provided with the information necessary to make informed decisions before agreeing to the import of such organisms into their territory. To date, biosafety regulation has focused on the movement of GMOs across national borders and their potential harm to ecosystem conservation and the sustainability of biological diversity.

The Cartegena Protocol on Biosafety is based on the precautionary approach, whereby the lack of full scientific certainty should not be used as an excuse to postpone action when there is a threat of serious or irreversible damage.

Such regulation will need to include a gene technology record, licensing of GMOs and permits. Licensing will require containment facilities, comprehensive risk assessment framework with monitoring and enforcement powers. Such a license will cover experiments, production, manufacture or import of GMO, possession, supply, use, transport, growth and disposal, including all intentional releases of a GMO into the environment. The licensing system should be based on open and transparent scientific risk assessment and consultation with expert advisory committees, industry, government agencies, and the public.

Other international agreements that need to be considered in the safe use of biotechnology include the WTO, TRIPS, IPPC, Codex alimentarius, Agreements on IPR under the WIPO, Regional Agreements and even National Regulations.

4.0 STATUS OF AGROBIOTECHNOLOGY IN THE CARIBBEAN

4.1 Regional policies

While there are no Caribbean-wide regional policies on biotechnologies, many countries of the Caribbean are actively researching and utilizing biotechnology in industry. One of the best known regional uses of fermentation is the production of world-renowned rums from sugarcane. It is obvious that with the exception of Cuba, there has not been a determined national commitment in the Caribbean to develop biotechnology. Recently, R&D investment on biotechnology in the Dominican Republic increased substantially but still a "State" commitment is lacking. Without policies designed to exploit biotechnology it is very difficult to advance in this field. Regional polices should include harmonization of regulatory framework, S&T cooperation; synergistically tackling of regional problems such a plant and animal diseases and germplasm exchange.

4.2 Educational Programs

There is an important amount of biotechnology courses available in the region at regional universities. The most comprehensive graduate programs are offered by Cuban universities. Others countries with graduate school capacity in biotechnology include the University of the West Indies on all three campuses in Jamaica, Trinidad & Tobago, Barbados; Dominican Republic and Puerto Rico. The teaching of biotechnology at the primary and secondary level is less advanced.

4.3 R&D situation

In the Caribbean, excluding Cuba (which has 60 agencies and ~ 1,500-2,00 agricultural researchers alone), there are approximately 150 different agencies at ~1,000 agricultural researchers conducting research in crops (56%), livestock (13%), natural resource management (14%), forestry (3%), fisheries (5%) or post-harvest (5%) production with most employing 1-10 full-time researchers[16]. Agricultural research expenditure in the region is very low and totally insufficient (Table 2). The region also holds a very small percentage of the world's patents (WIPO data).

Research in biotechnology is growing in the Caribbean. The most developed countries in terms of agrobiotechnology are Cuba, Jamaica[17], Barbados, Puerto Rico[18], Trinidad and Tobago[19] and Dominican Republic. Guadeloupe has the most funds recently invested in agricultural research (Table 2). Cuba and Puerto Rico have the most developed infrastructure. The larger Caribbean islands have more infrastructure, human resources, technical know-how, biotechnology programs and allotted funds than the smaller islands. Some of the smaller islands hardly carry out any agriculture at all and their mainstay is tourism and services (see Table 1). The trend in R&D is towards adaptive research. Financial support is insufficient. Entrepreneurial and innovation training in biotechnology is low to non-existent.

A Caribbean Biotechnology Network directory compiled in 1991 listed 12 countries and 57 scientists in the Caribbean who were in some way involved in Biotechnology[12]. In 1999, at a meeting in Dominican Republic, Cuba alone reported having 128 PhD, 129 MSc, 404 other professionals and 504 non-professionals involved in agricultural and livestock biotechnology research and 832 in production-marketing. The corresponding values for the Dominica Republic were 7, 6, 36, 42 and 0.

[16] ISNAR Research Paper Report 19. Agricultural R&D in the CAribbean www.isnar.cgiar.org/publications/pdf/rr-19.pdf , June 2001

[17] McLaughlin, Burrell and Barnett (2003) Applications of Biotechnology in Jamaica and the Caribbean

[18] Morell (2002) Biotechnology Research in Puerto Rico: The synergy between Academia, Government and the Private Sector, Presented at the Second International Corporate/Academic Roundtable on Emerging Technologies http://www.wpi.edu/News/Conf/Molecular/Presentations/lueny.pdf

[19] Dottin M (2002) Summary of current and future biotechnology development in the Caribbean

The smaller Caribbean countries main biotechnology activity is tissue culture (Table 5). Despite the number of professional biotechnologists in the Caribbean, the effect on agriculture is not being realized due to small size and dispersion of research groups, poor linkages and collaborations, faulty links with the productive sector, poor understanding and use of the intellectual property system, inadequate recurrent funds and the absence of effective and efficient national and regional programs to organize and promote scientific activities and advances.

The region has recently put some emphasis on agricultural research and development. New high yielding varieties of rice and other crops are being introduced while training programs are ongoing at various levels in regional universities. The European Union has just finished a regional agricultural and fisheries program, which included a component of commercial research and training. In addition, regional cooperation entities such as the Caribbean Agriculture Research and Development Institute (CARDI), the Inter-American Institute for Cooperation in Agriculture (IICA) and the United Nations Food and Agriculture Organization (FAO) are very active in the region's agricultural sector.

- **The Cuban case**

Evidently, Cuba is a case to study as a potential scientific and technological resource in the Caribbean region. More than 30,000 people work in Cuba's 153 research centers and in the research and development areas of its most important enterprises. Forty-seven percent of them are women, more than 8,000 of whom are university graduates, including 5,338 researchers. In 1997, there were 5,231 Ph.D.s, nearly 13 percent of them in the biomedical sciences. There are around 24,000 university professors for the more than 130,000 university students, and they devote part of their time to research diverse areas of science and technology. A great deal of effort has been put into biotechnology, resulting in an extraordinary advancement in medicine and crop improvement.

Interferon served as the model product for Cuban biotechnology. At first -- in 1981-- natural IFN was produced from human leukocytes. This product was named Leuferón and was marketed by enterprises connected with the Ministry of Public Health. The CIGB [Center for Genetic Engineering and Biotechnology] was created in 1986. By mid-1997, its researchers and those of the CIB, working together, had obtained more than 200 products. The CIGB occupies an area of 72,000 sq. metres. Its eight-story main building has 43,200 sq. metres of laboratories and a 8,000 sq. metres production plant, with a micro plant and various production areas, including fermentation, recovery, purification and preparation of materials and culture media, a process-control laboratory and a building for auxiliary systems.

- **The Puerto Rican Case**

Just like Cuba, Puerto Rico is an extraordinary source of scientific and technological inputs. Most American universities have research and training programs within the Puerto Rican university's system. In a future Caribbean capacity building agenda, Puerto Rico should be considered as a very strategic ally.

The Puerto Rico Cluster of Biotechnology is a model on how to foster partnership between academia and industries. The Puerto Rico Biotechnology Alliance was formed in 2001 to serve the growing biotechnology industry cluster in Puerto Rico[20]. Their mission is to foster a competitive and innovative world class biotechnology industry. We aim to be the preferred partner for biotechnology enterprises in Puerto Rico.

- **The Dominican Republic Case**

Recently, in the Dominican Republic, a significant amount of effort has been oriented to push forward a national biotechnology agenda. An investment of near 1 million USD per year has been allocated for the establishment of the Biotechnology and Biodiversity Centre (CIBIO). CIBIO's working areas

[20] Biotechnology Alliance Member Organization list: Eli lilly, UPR-RUM, INDUNIV, AMGEN, Grupo Guayacan, Fomento-OCT, Deadalus, Ponce School of Medicine, Lockwood Financial Advisors, Ortho, Abbott labs, Natural Sciences, RRP, Biomedical. Sciences, (UPR-RCM), Bacardí Corp.

include tissue culture, molecular diagnostics, molecular biology, germplasm management, industrial biotechnology and nutraceutics. Also the Dominican Institute of Industrial Technology, (INDOTEC) reopened its Biotechnology Department in April 2004 and is involved in projects related to fuel ethanol and L(+) lactic acid fermentation from sugar cane, and with the incipient Dominican wine industry. The major advancement in the Dominican Republic during the last three years includes the following:

- Established advanced laboratory facilities in the areas of tissue culture, molecular diagnostics, molecular biology, nutraceuticals, bioprocess, germplasm management and genology.
- Created the Biotechnology Masters Degree Program (18 students) in partnership with two national institutions (Superior Agriculture Institute – ISA; the Agriculture and Forestry Development Centre – CEDAF) and Ohio State University.
- Organized a local Biotechnology Group (Dominican Biotec Group) comprised of commercial laboratories.
- Established production protocols for a wide variety of biotech products (biopesticides, medicinal extracts, fruit wines, diagnostic methods, molecular biology routines, scale-up of tissue culture protocols and cell suspension systems). Results include:
  - Extracts from twenty (20) endemic plants with bioactivity against human and plant pathogens are currently being studied and testing is ongoing;
  - Development of a semi continuous fermentation system for food grade L (+) lactic acid from sugar cane juice. Preliminary assays currently being carried out;
  - Validation of DNA and RNA extraction and purification protocols for a range of crops, including avocado, rice and plantain;
  - Production of a biopesticide from *Beauveria bassiana* to control the coffee berry borer (*Hypothenemus hampei*). The biopesticide shows 99% activity *in vitro*; trials are being carried out in field coffee trees;
  - Validation of molecular diagnostic protocols for plant pathogens, including PCR, ELISA, and immuno-printing methods for the detection of Tristeza virus in citrus and banana black sigatoka;
  - Temporary immersion system for the propagation of plantain, ornamentals and orchids;
  - Improvement of production protocol for pure ethanol from sugarcane as biofuel as a means to diversify the sugarcane industry and generate fuel from renewable sources.

- **The Jamaican Case**

The challenge in Jamaica recently has been on how to develop biotechnology in an austere financial environment. Most if not all research and development institutions in the country have recently experienced budget cuts. Recent developments include:

- The Biotechnology Centre at UWI, Mona was opened in 1989, and the Molecular Biology building in 1998. Between them at least 30 undergraudates and several graduates trained in biotechnology-related subjects are produced every year;
- At the Biotechnology Centre there are research groups in molecular-marker assisted breeding, transgenic plant research (papaya, cotton and pepper), gemini viruses, root & tubers, and medicinal plants;
- The Natural Products Institute, UWI was opened in 1999 to encourage and consolidate previous research and development in natural products;
- The coconut board has a biotechnology laboratory concentrating on the elucidation of lethal yellowing;
- The Scientific Research Centre has biotechnology-related research groups in tissue culture, plant-disease diagnostics, biogas and nutraceuticals/essential oils;
- The University of Technology provides training in biotechnology engineering.

In the last year, the trend has been towards developing consortiums and collaborations to maximize efforts. The development of a national biotechnology strategy and policy is also ongoing.

The only commercial tissue culture businesses are in orchids that have been in operation since the 80's. The Scientific Research Council has an *in vitro* gene bank having the largest collection of *Musa* (banana) in the Caribbean, also other varieties including ackee, papaya, jackfruit and bay rum.

Policy developments are favorable. The Jamaica Intellectual Property Office achieved statutory status in 2001 and has been busy upgrading IP legislation; in 2004 the geographical indications legislation came into law. The Jamaica Organic Agriculture Movement was formed in 2001 and by 2003 had developed a certification program for farmers, with certified Inspectors now being available.

Recent results include:

- Development of several formulations from locally-grown medicinal plantst hat are now market-ready;
- Improved planting material by collaborative efforts of several agencies – eg tomato, hot pepper, sorrel and coconut;
- Continued development of the mushroom and biogas industries;
- Continued development of value-added products from established and new agricultural crops eg sorrel chutney, xanthum gum, essential oils;
- Closer collaboration between academia, government and productive sectors especially for the development of products from locally-grown medicinal plants.

- **The OECS Case**

Several of the Eastern Caribbean States have publicly-owned tissue culture laboratories[21]. The primary responsibilities of these laboratories have been germplasm conservation, research and "commercial" micropropagation to supply growers with vegetative planting material. Due to limited capacity (growth chambers and equipment) and inadequate staffing, these mandates are not being properly fulfilled.

In spite of inadequacies, there are success stories. The CARDI lab has four growth chambers and a low temperature chamber, supplying planting material to Montserrat and St. Kitts (who do not have tissue culture laboratories) and has provided commercial quantities of some planting material (banana, plantain and anthurium) to many countries (eg Grenada, St. Vincent and Trinidad) in the past. This facility, however, is in need of major repair and resupply.

The laboratory in St. Vincent has 7 laminar flow hoods and 3 autoclaves and has the capacity to produce 140,000 banana, 30,000 pineapple, 5,000 orchids and 5,000 dasheen plants annually. Grenada has a capacity for 200,000 banana plantlets annually. The reported annual capacity of the Ministry of Agriculture lab in Barbados for anthuriums is 1,000,000. The facility in Grenada has recently acquired a bioreactor while CARDI has temporary immersion equipment.

The following activities are being carried out:

- *Germplasm conservation:* cultivars indigenous to the region are being conserved. These include conservation in St. Vincent (25 varieties of cassava), Guyana (16 cultivars of sweet potato), Barbados (14 varieities of sweet potato) and St. Lucia (8 varieties of yam).

- *Introduction of new germplasm:* movement of germplasm across international borders through tissue culture eg germplasm from Columbia (cassava) to St. Vincent, CARDI obtained germplasm from Columbia (cassava) and France (banana) which it hardened and distributed to St. Vincent, Montserrat and Trinidad. Presently CARDI is processing certified sweet potato varieties from CIP for local farmers. After the devastating effects of the volcanic eruptions in Montserrat, CARDI supplied cassava plants for replanting.

- *Rapid multiplication of quality planting material:* uniform and disease-free banana plantlets have been supplied by CARDI to St. Lucia, Grenada, St. Vincent and Trinidad in the past. Grenada is currently producing pineapple plantlets for Puerto Rico.

- *Disease-free planting material:* Currently a viral complex that is reducing productivity infects sweet potato varieties. One of the strategies being used is importation of disease-free material from CIP.

[21] This section is summarised from an unpublished preliminary report of CARDI biotechnologist Dr. Cyril Roberts to the board of directors, May 2004

- *Research:* adaptation of standard protocols for optimization. CARDI is also experimenting with regeneration of plants from hot pepper explants to complement the regional hot pepper improvement program.

- **The T&T Case**

Presently, biotechnologies are increasingly being used in Trinidad and Tobago at the Forensic Science Centre, CAREC, CARIRI, food and beverage manufacturers and in diagnostic and tissue culture laboratories. The service industries that can provide various biotech services locally and regionally, include services in genetic screening, disease diagnosis, DNA fingerprinting & forensic services, DNA sequencing, gene therapy and drug efficacy monitoring services, intellectual property services, bioremediation of industrial & other wastes, biopesticides, monitoring human activities for sustainable use of biological resources etc. It can be said that biotechnology is poised to revolutionise every industry in Trinidad and Tobago.

The UWI St. Augustine campus (UWI-SA) has developed a vibrant research group in recent years and research is being carried out in a number of areas (Table 6 and 7). The UWI-SA has a biotechnology facility, and an active biotechnology group, which has been involved in biotechnology research for the past 15 years. Early work at the biotechnology unit centre was the development of micropropagation protocols for several tropical plant species. Since then, the biotechnology group has evolved and is working on molecular diagnostics, genomics and genome mapping, bioengineering, biopesticides and bioremediation. Research is being carried out in agricultural biotechnology, microbial biotechnology, medical biotechnology and environmental biotechnology.

Although there is no coherent policy on biotechnology in Trinidad and Tobago, the Government has developed some enabling policies and legislation. T&T is also signatory to the UPOV convention on plant variety protection and the Cartagena Biosafety Protocol, which deals with the safe use of genetically modified organisms and foods. Legislation on intellectual properties, especially those related to the protection of biological innovations has been developed. This should encourage private investments in biotechnology. There is yet no clear biosafety policy or legislation, although a National Biosafety Committee has been working on this for some time. This legislation is important not only to provide a regulatory framework for biotechnology, but also to address WTO stipulations.

Upcoming plans include:

1. Trinidad and Tobago is the only member country of the International Centre for Genetic Engineering and Biotechnology (ICGEB). The ICBEB was established by UNIDO to bridge the gap between developed and developing countries with respect to biotechnologies. The ICBEB serves as an intermediary in acquiring and disseminating technology to developing countries. UWI is working with the Govt of Trinidad and Tobago to establish a regional centre of the ICGEB so that ICGEB technology transfer programmes can be made available to the region.

2. A UWI-Wide MSc programme with three streams, i) research and innovation stream, ii) a stream dealing with biosafety, IPR, ethics and creating an enabling environment and iii) a stream dealing with industrialization of biotechnology. Specific areas of the programme will be delivered as diplomas. The programme will be made available across the region at a reasonable cost. This could be used a capacity building programme for the regional agrobiotechnology effort.

3. The UWI has identified Biotechnology as one of five major thrust areas of research. A UWI-wide research team has been assembled with campus coordinators for biotechnology in the three campuses. This has helped to build a critical mass of scientists with the capability to compete for large grants. This will also avoid duplication of efforts and lead to greater focus and collaboration.

Regional research efforts should be driven by grants involving many regional institutions. Such efforts would bring regional institutions closer together and would bring the critical mass of multidisciplinary expertise distributed in the Caribbean islands together. A few projects such as these would provide the momentum for future projects.

All research efforts should be closely linked to the industry so that the research and innovations will lead to efficiency in the industries. This will also ensure that the technologies developed are appropriate. The UWI is developing University-Enterprise partnership in research to ensure that the research will result in productivity gains.

4.4 R&D projects

The development of biotechnology in the Caribbean in the last ten years has been impressive. Many new research groups and educational programs have been developed. The critical mass to make things happen is being reached. There are many crucial and exiting research and development projects taking place as can be seen in Tables 3-5. There are also many national and regional groups undertaking biotechnology research and development in the region (Table 6). The region is poised to see this R&D be transferred to the market place if the right mechanism can be found.

A summary of R&D in Trinidad and Tobago and the eastern Caribbean states (OECS) is given in a document pulled together by REDBIO[22]. As yet, however, there is no directory where all the biotechnology R&D projects in the Caribbean can be found. Many biotechnology projects relevant to agriculture in the region can be found at the region's university web sites but are scattered. The OAS has a page listing S&T indicators such as the number, types, publications, patents etc but the information is not up-to-date and does not cover all the islands in the Caribbean[23].

There are many examples of Caribbean biotechnology being applied to agriculture[24].

- the use of agricultural waste to grow mushrooms;
- the use of waste to make biogas;
- composting of agricultural waste to make organic fertilizer;
- the use of fermentation to make rum, wines and liquors;
- the use of tissue culture to produce disease-tested tropical crops such as yam, banana, neem, pineapple, plantain and ginger;
- the use of genetic engineering and molecular techniques to develop disease-resistant tropical crops;
- Development and field testing of transgenic papaya;
- Development of disease-resistant anthurium, banana, tomatoes, hot peppers and cassava;
- Determination of biochemical pathway of colour in anthuriums;
- Production of xanthum gum from molasses (value-added product from sugarcane);
- Locally developed organic fertilizers and bio-pesticides;
- Determination of the nature of tropical crop plant diseases (especially gemini-viruses);
- Identification of plants using DNA fingerprints.

See also Tables 3-5.

4.5 GMO situation in the Caribbean

Several islands of the Caribbean have produced transgenic plants (Cuba, Barbados, Jamaica, Trinidad & Tobago, U.S. Virgin Islands), but only in Jamaica (papaya) and the USVI (papaya, sweet potato, cassava) are there transgenic plants in the field, and only in the latter are they deregulated. The transgenic papaya in Jamaica are still under tight regulatory control and have yet to be released to the public. Most of the larger islands are either producing (Cuba) or have the capability to produce transgenic plants. At the moment most of the islands are establishing biosafety regulations and strengthening their intellectual property laws and policies. The largest deterrent to deregulation of transgenic crops in the Caribbean appears to be reluctance on the part of its markets to accept GMOs.

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[22] http://www.redbio.org/html/Content.PDF
[23] S&T indicators http://www.science.oas.org/RICYT/Indicadores/indicadores_eng.htm
[24] Mitchell and Ahmad (2003) **Agricultural biotechnology in the Caribbean** A gBiotechNet (ABN 106)

4.6 Industrial development of agrobiotechnology in the Caribbean

All types of biotechnology endeavors are presently being practiced in the Caribbean, although not all islands are at the same level of development (see Table 3-4). While most of these practices are still at the research level, a fair level of innovation is beginning to be apparent and this is encouraging. More data collection and analysis is needed.

At the national level in the Caribbean region, there are many cases of relevance in the advancement of agro-biotechnology as seen for example, in Cuba and Puerto Rico. The case of Puerto Rico is outstanding as it benefits from the "spillover" effects of US technology companies established in the country, as well as the existence of universities with extraordinary installed capacity in terms of infrastructure and human resources for undertaking bio-technology research. In this regard also, Cuba is an unusual case worthwhile noting. The Cuban government has invested millions of dollars in the development of biotechnology at all levels, and is reaping sizeable benefits from this investment. Today Cuba has one of the "state of the art" installations in the Americas conducting work in plant and animal biotechnology. The rest of the countries in the Caribbean are struggling to access the benefits biotechnology has to offer.

The questions that remain include: how many patents does the Caribbean hold in agricultural biotechnology? How are they being utilized?

4.7 Public Perception

Not everyone is convinced of the advantages of biotechnology. To be fair, advantages and disadvantages can be found. Opposition to biotechnology is mainly on ethical and environmental grounds – the feeling that humans should not be moving genes around, and that the environment may suffer unduly. Others feel that biotechnology companies own what should be free to all, especially genes and the altered organisms. The European Union presently does not allow the growth or importation of genetically modified food crops or derived products and indeed is the centre of the organic farming movement. The two systems are developing as alternatives to each other as organic farming does not allow the use of GMOs although it may allow the use of tissue cultured planting material. There are no published studies available that have studied public perception in the Caribbean towards application of biotechnology to agriculture.

4.8 Regional databases and other initiatives

There are plenty of databases that could be of great use for Caribbean scientists (see Table 8). A particular one is InfoREDBIO (http://www.redbio.org/rdominicana/inforedbio/marcoregulatorio.htm), whose major objectives is to offer services related to biotechnology and to gather, store, and share information on the field throughout Latin America and the Caribbean. The goal is that all 32 participating Latin American and Caribbean countries at project's end will have the capacity to implement and enforce standardized criteria in the areas of biosafety, food safety, intellectual property, agricultural crop quality, so as to facilitate access to important markets (such as the United States and Europe) and biotechnology products (such as nutraceuticals, GM crops and others). The Dominican Republic and CIBIO host the regulatory component of InfoREDBIO.

CARIRI has played a pivotal role in the establishment a biotechnology network (SIMBIOSIS) for the English Speaking Caribbean.

4.9 Regulatory Framework

Several countries in the Caribbean have begun to put in place policies dealing with biosafety as part of their obligations under the CBD and the Cartegena Protocol with financial support from UNEP/GEF.

There is as yet, though, no workable regulatory framework for the Caribbean as a region. Also, there are many countries that have Intellectual Property Offices but there is as yet no Caribbean-wide patent system such that one patent can cover the whole Caribbean region.

Recently (January, 2004) a regional workshop for CARICOM countries was conducted in the area of risk assessment and management (Organised by NIHERST with funding from IDRC), with the objective of harmonizing regional efforts. The discussion led to the development of consensus documents on harmonization of national biosafety frameworks, guidelines etc. These documents are available.

Within the Caribbean there is recognition of the need for Environmental Health (waste management, biodiversity, conservation, risk assessment and management, ecological coexistence) and Agricultural, Health and Food safety. There are also increasing regulations such HACCP, GAP, traceability, risk assessment as required by the market. Certification for Differentiated Agriculture (Organic) is also being put in place. However, these efforts are being developed separately and need to be co-ordinated.

5.0 CHALLENGES AND MAJOR PRIORITIES

In this context, agro-biotechnology should be looked at in its widest ambit but focus should be placed on those areas that present the best opportunities for the region. Both plant and animal agrobiotechnology represent good opportunities for the region. The areas of application should include but not necessarily be confined to those concerned with the production of seeds, genetic improvement, diagnostic system, bio-processing, bioinformatics, bio-prospecting, the management of bio-diversity, reproductive biology, regulatory standards and support for trade related biotechnology issues as well as biotechnology business (bio-parks and business incubators).

Biotechnology applications should be seen in the regional context as a means to an end and not an end in itself. It is a tool for the development/enhancement of agriculture in the Caribbean and as a mechanism for the utilization and conservation of regional bio-diversity in a sustainable manner in order to generate added prosperity. The strategy should be relevant to all or most of the countries of the Caribbean notwithstanding their heterogeneity

5.1 SWOT analysis

5.1.1 Strengths

The Caribbean is strategically placed. It is near the major markets of North America and is surrounded by giants in Biotechnology including the USA, Mexico and Brazil. The Caribbean, although lacking in size has many commodities that are world renown for their superior taste such as ginger, pimento, and coffee. The Caribbean also has many endemic crops that are seriously underutilized. There is also a large and virtually untapped potential for value-added products.

5.1.2 Weaknesses

The Caribbean is divided by geopolitical fragmentation and financial limitations. The small size of the islands of the Caribbean makes economies of scale impossible. There is no functioning networking in agricultural biotechnology in the region besides personal connections. This is especially obvious in the schism between the English Caribbean (CARICOM) and the other groupings in the Caribbean eg Spanish-speaking Caribbean (Cuba, Dominican Republic, Puerto Rico), the French (Haiti, Guadeloupe, Martinique) and the Netherlands Antilles. The Caribbean has not made use of information available in regional and interregional data bases due largely to lack of support mechanisms for researchers. Neither has the region made full use of opportunities to develop agrobiotechnology by use of existing financial programs due to lack of knowledge or capability to access them. In many countries, the level of research is low to non-existent while the countries that have forged ahead have not brought the other countries with them.

5.1.3 Opportunities

Biologically based technology (biotechnology) is a promising source of new products and new uses for farmers. It is a collection of powerful tools that can to be used to increase production or cut costs, develop product attributes desired by consumers, or enhance environmental quality. It is a production, processing, consumer-orientated, and information technology that has application in not just one, but every segment of the food supply chain[25]. There are opportunities in the Caribbean for the development of niche markets.

5.1.4 Threats

The Caribbean is affected by factors over which it has no control such as the cost of fuel. Only T&T in the region has its own energy source. It is affected by natural phenomena such as hurricanes and climate change. These factors affect the competitive advantage of any endeavour undertaken in agricultural biotechnology. Competitive advantage is also being affected by globalization and loss of

[25] USDA 2001

preferential markets. Most of the countries in the region are developing states and have to compete with other needs for inadequate resources.

5.2 Challenges

In order to decrease the effect of weaknesses and threats and to maximize the strengths and opportunities available to the Caribbean, there are many challenges and hurdles to be overcome. Some of these challenges are listed below.

- Training of skilled human resource personnel;
- Acquisition of state-of-the art equipment include DNA sequencers, bioreactor and computers;
- Access to ongoing training sessions and regional/international conferences;
- Allocation of sufficient funds – for research and for commercialization of these research results;
- To take results to the field, monitoring mechanisms and policies have to be devised, and interaction with farmers encour aged;
- A two-way stream of information to- and from- farmers is needed;
- Scientists will need to become more business minded and agricultural business personnel will need to become more science minded;
- A culture of science and technology, and respect for scientists, will need to be encouraged or locally trained personnel will migrate;
- Finally, the government will need to take policy decisions to encourage this growing sector.

In developed countries such as the United States university-industry collaboration has resulted in the spin-off of many biotechnology countries. For such results in the Caribbean, some critical problems have to be solved[26]:

- Technical constraints: The inability of many scientists to transform basic lab findings into pilot scale bio-industrial processes;
- Economic loans: The lack of economic loans, incentives and risk capital for the development of small scale biotechnological enterprises;
- Professional experience and facilities: The lack of experienced researchers, extension services, product ion facilities, marketing managers and a local market large enough for biotechnology -based business;
- Public perception: Insufficient public sector perception, and a low appreciation by the general public;
- Strategic planning: Long-term strategic planning by the university and industry executives of small nations for future development and growth.

5.3. Creating National and Regional Capacities

There is no panacea or mathematical formula that can ensure the success of a regional biotechnology agenda in the Caribbean. However, it is important to work from a conceptual framework that can guide a regional effort to fruitful results in the long term. Reflection on other Latin American experience allows an understanding of what it takes to carry out a biotech program within the Caribbean states. A conceptual approach, termed **"NovoBiotransfer"**, has recently been elaborated in the Dominican Republic. This approach is designed to facilitate the advancement of agricultural biotechnology.

In brief, **NovoBiotransfer** is a model that advances biotechnology by emphasizing innovation and technology transfer over the long term. Innovative inputs range from fundamental science to its most removed applications, with the simple goal of providing solutions to meet the many needs of humanity. Biotechnology transfer encompasses the adaptation and implementation of biotechnology packages from one country to another or from the laboratory to the farm.

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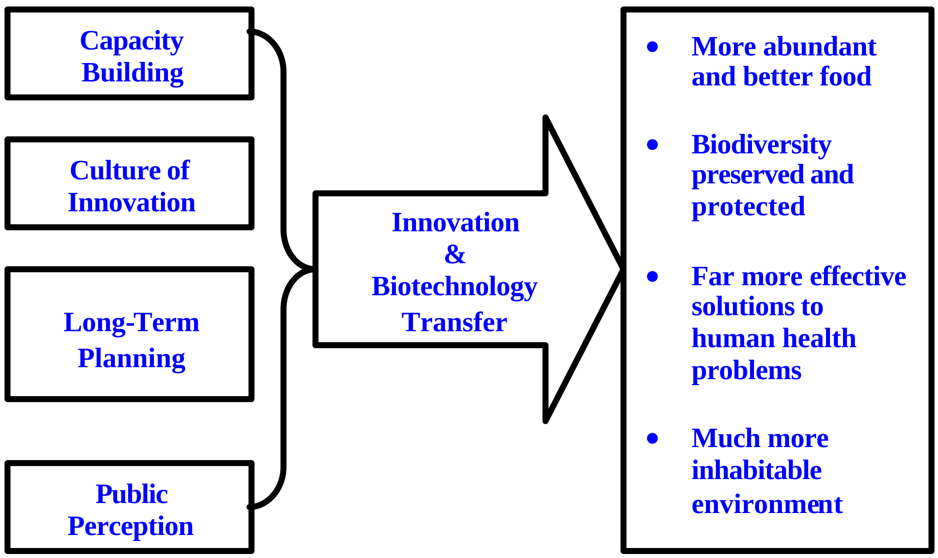
[26] Ahmad MH (2000) Growth and sustainable development through university and indu stry collaboration in biotechnology. In: Contending with Destiny: The Caribbean in the 21st Century. Ed K Hall and D Benn, Ian Randle Publishers, Kingston, Part 4: Science, Technology and Development, Chapter 15 pg 147-153

The **NovoBiotransfer** model is guided by the following rationale:

1. A long-term vision must be adopted both nationally and regionally, in order to take advantage of benefits derived from biotechnology. A collective perspective is needed to take advantage of complementarities among national and regional biotech agendas.
2. Biotechnology is a means, not an end. Its development should result in the improvement of human welfare.
3. While developing biotechnology and utilizing its products, sustainability should prevail.

NovoBiotransfer Conceptual Layout



5.4. Capacity Building in the Caribbean

Capacity building is one of the most important aspects in designing and implementing a biotechnology development agenda in the Caribbean countries. Several essential elements ought to be taken into account:

- *Human capital.* Biotechnology, in its complete spectrum, is a complex thematic and thus it is very difficult to put forward a biotechnology program without a critical mass of scientists. It could be seen at different levels: at a laboratory level, at a country level and as a region. With adequate physical facilities, world-class scientists constitute the most important element to innovate and transfer biotechnologies, resulting in direct benefits to people. Countries such as Chile have carried out the exercise to estimate the size of that critical mass of scientists that would be enough to sustain a national biotechnology agenda. Chileans have estimated that within the next 10 years, they need at least 500 hundred world class Ph.D. scientists working on biotechnology in areas that would bring better opportunities and competitiveness to them as a country.

  It is also extremely important to understand that the human capital means the whole range of individuals in the chain, relevant to the biotechnology advancement. Therefore, it is intelligent to think that behind world class Ph.Ds, there is also a whole batch of people contributing to innovation and biotechnology transfer. These people also need to be brought abreast of modern biotechnology. In general, two very important components should make up a human capital critical mass to put forward in a sustainable way a biotech agenda: a) formal education and b) informal training.

- *Physical facilities.* Caribbean countries need to make sufficient investment to establish adequate infrastructures. Both at the level of universities or national research institutes, the facilities should exist. In average, developing countries invest less than 0.03% of the NGP. These facilities should continuously be optimized so the innovation and technology transfer process occurs with the advancement front.

- *Regulatory Framework.* A regulatory framework should be established or strengthened both nationally and regionally. At a regional level, harmonization of regulation systems is critical. Important elements to be taken into consideration include intellectual property, biosafety and food safety.

The capability of a country or a group of countries to optimize the benefits derived from biotechnology depends, in great extent, of its capacity to incorporate modern technologies into its research and innovation platform. A scientific base is the driving force for innovation, and the availability of local research and development capacity has became critical in a field that is getting more and more knowledge-intensive. Therefore, while as a group Caribbean countries should work synergistically together to harmonize regulation policies so transfer and exchange of biotechnologies would be possible, it is also true that each country needs to develop its own capacity. This way, biotechnology is not exploited only by a few countries.

5.5. The need for a regulatory framework for biotechnology and biodiversity: a major priority for the Caribbean

For a wide range of complex reasons, including trade concerns, the lack of an adequate regulatory structure and resources, and the fact that much of the biotechnology research and development has focused on crops that are not suitable for the Caribbean crop systems, most countries in the region have not yet benefited from biotech crops. To date, adoption has primarily been limited to tissue culture. The urgency with which in the Caribbean it is needed to work on the formulation, revision and updating of regulatory framework both at a national and regional levels is evident. Many countries have already started the assembling of the framework: Cuba, Jamaica, Dominican Republic, Trinidad and Tobago, and Guyana.

A national bio-regulation council could provide the following:

- Propose national biosafety policy;
- Execute policy changes as science advancements occur to make regulatory framework more suitable;
- Establishment of regulations to authorize or prohibit the manipulation, release, farming, transport, export, commercialization and consumption of genetically modified organisms;
- Prepare technical reports, based on risk assessment on the use GMOs;
- Assist related institutions on the process of evaluating accidents and diseases, derived from the use of genetic engineering;
- Make public relevant reports on issues of relevance such as biosafety, food safety, differentiated Agriculture (Organic Agriculture) and intellectual property;
- Guarantee traceability of national products both for local and export markets.

6.0 AGRICULTURAL BIOTECHNOLOGY OPPORTUNITIES

There are many biotechnology opportunities that can be used to enhance Caribbean agriculture. A descriptive framework to organize these techniques has been developed (see section 6.1). There are many crops for which the Caribbean has a competitive advantage as outlined in section 6.2. Analysis of market information and trends will be used to focus this list. There are many biotechnology capabilities that will need to be developed as a platform to work on any crop as outlined in section 6.3.

6.1 Opportunities of biotechnology for agriculture

Utilization of Biotechnology must make agriculture more profitable and therefore more competitive. In order to do that the Caribbean requires improved germplasm (1), large-scale production of germplasm stock (2), improved cultural systems (3) and development of value-added products from agricultural crops (4). The opportunities of biotechnology for agriculture can therefore be summarized as stated below:

1. Improved germplasm
    a. Disease-indexed plantlets through tissue culture – tc facility and techniques, ELISA, id pathogens
    b. Support for breeding - molecular marker assisted selection, germplasm evaluation, biochemistry
    c. Biodiversity / Identification of genes – molecular biology, sequencing
    d. Embryo techniques – animals, ornamental fishes
    e. GMO – transformation, PCR, biolistic, agrobacteria, regeneration
    f. Quarantine systems – biosafety regulation, indexing material coming in and going out
    g. Low cost, high quality
2. Large-scale production of germplasm stock
    a. Micropropagation – techniques and equipment
    b. Somatic Embryogenesis (synthetic seeds)
    c. Temporary immersion (bioreactor)
    d. Animal foundation stock (artificial insemination, embryo transfer)
3. Improved cultural systems
    a. Biopesticides
    b. Identification of fungi and bacteria using molecular techniques
    c. Diagnostic kits
    d. Urban agriculture – callallo etc
    e. Hydroponics
    f. Organic agriculture – composting, soil inoculants, amendments, solarization, crop rotation, companion crops, biopesticides
    g. Protected precision agriculture - Greenhouse systems
    h. Marine – fishery, mariculture
    i. Production and post-harvest techniques
    j. Can be integrated into different systems
4. Value-added products – need to be competitive
    a. Biomass
    b. Ecotourism
    c. Bio-pesticides, bio-inoculants, bio-fertilizers
    d. Extracts – eg essential oils, orange oils, pimento oils, khus khus grass, flavors, pharmaceuticals
    e. Fortified foods – nutraceuticals
    f. Fermentated products – lactic acid, wines, rum, liquors, pickles, diary and other products
    g. Use of waste – mushroom
    h. Bioremediation -oils
    i. Gums and resins - Xanthum gum
    j. Pigments, natural dyes - annatto
    k. Fiber and energy crops – sisal, production of algae, energy crops, eg sugarcane to ethanol

6.2 Products

There are many products for which the Caribbean has a competitive advantage. The following list is not exhaustive but represents the potential for development and needs to be further refined into priority areas.

1. Tropical fruits and flavors – papaya, mango, guava, passion fruit, pineapple, soursop, star fruit, sapodilla, tropical strawberry, citrus;
2. Spices / aromatic / medicinal plants – hot peppers, escallion, garlic, thyme, chives, nutmeg, arrowroot, marjoram, spirit weed, pimento - region has at least 600 herbal/medicinal/spice plants – includes Nutraceuticals, Functional Foods, flavours;
3. Fibre – sisal (agave);
4. Crops for niche markets – eg for certified organic agriculture (bio-pesticides), organic cacao, WI cotton, oriental vegetable;
5. Crops for special by-products – eg special extracts – lactic acid, propanol, gums (resins), Crops for biomass for value-added products eg sugar-cane to lactic-acid (low tech, 5x use of sugar) (used to make biodegradeable polymer, and many other uses), tropical oil crops (coconut);
6. Tropical ornamentals, cut flowers, foliage – eg orchids, anthurium, palm trees, endemic flowers, bromeliads;
7. Eco-tourism – forestry, herbals, biodiversity, coconut oil;
8. Animals - Livestock, pig, pork, tropical ornamental fish, birds, monkeys, frogs, arachnids (gene mining – pharmaceuticals, poisons), specialized animal breeding eg Chihuahuas;
9. Food security crops – must be available in time and space and populations have to have purchasing power – includes human food, and also feed for animals – rice, beans, meat, root and tubers, plantain, green banana, milk, poultry;
10. Marine products – spirulina, aquaculture, shrimps etc, gene mining;
11. Bioinformatics – biostatistics, genomics.

6.3 Capacity building

1. Fermentation
2. Tissue culture/cloning
   a. Micropropagation and Somatic embryogenesis techniques
   b. Secondary metabolite production
   c. Disease-indexed plants
3. Molecular Biology
   a. Marker-selected breeding
   b. DNA fingerprinting for the identification of viruses, fungi, bacteria, plants and animals
4. Genetic engineering
   a. Sequencing
   b. Transformation

6.6. Bio Parks in the Caribbean

The Bio Park concept can be described as a science and technology platform to enhance business opportunities in the field of biotechnology through the development of products and the generation of services as a means to foster the competitiveness agenda of given country or region. The bioparks are similar to the free zone-type systems that already exist in the Caribbean region, with the particularity that it is specialized in the biotechnology field. The bioparks house specialized service laboratories and research and development companies. There is a tight link between the bioparks and universities, so that human capital grows and innovation and technology spills over.

7.0 THE PROPOSED STRATEGY – Conceptual umbrella

The Caribbean region is made up of disparate geopolitical states with various affiliations, laws and desires. However, these differences need not be a weakness. They can be harnessed to produce wealth through innovation. An agrobiotechnology agenda, to co-ordinate efforts, will allow the development of the necessary platform and framework to enable the safe use of biotechnology for agricultural development throughout the region. A great deal of agrobiotechnology products and packages are available throughout the world thus representing a wide range of opportunities for the region. The Caribbean itself is increasingly participating in this process and has developed many innovative agro-biotechnologies that are producing wealth in the region (eg Cuba). The agenda proposed in this discussion paper will enable the development of endogenous Caribbean capability in agrobiotechnology according to the priority needs and opportunities of the region. In order to develop a working platform, agenda, a way forward, it is necessary first to obtain a critical mass of scientists, which we now have in the Caribbean. Previous efforts towards collaboration have shown us our weaknesses and we can build on the lessons learnt. To make judicious use of this critical mass of agro-biotechnologists in the region, we now need to co-ordinate our efforts for our own sakes. An agenda that does not produce the results we want, will not succeed.

7.1 General objectives

It is a main aim of the CGABC to strengthen the capacity of the region for the development, management and safe use of agrobiotechnology. This installed capacity then shall foster a sustainable and competitive agriculture in terms of generation of prosperity, food security, equitable distribution of wealth and health while protecting the environment and endemic biodiversity. This is to be achieved through the integration of efforts by countries in the region in terms of policies, technical development, and mobilizing key stakeholders of the public and private sector, toward the enhancement of a better standard of living for the Caribbean people.

7.2 Specific Objectives

- To help establish guidance for the exploitation of biotechnology within the region
- To help a better management, conservation and use of Caribbean genetic resource and biodiversity
- To provide up-to-date information and analysis on key agro-biotechnology issues for decision making process in the Caribbean.
- To support the design and harmonization of policy norms and regulatory framework.
- To strengthen regional agrobiotechnology R&D capacity.
- Capacity building in agrobiotechnology
- To support commercialization of biotechnology products and processes.
- To increase public awareness of the potential of agrobiotechnology.

7.3 Components

7.3.1 Information and prospective analysis

Technology is developing very rapidly. In order to access this technology (bioinformatics, locally and internationally developed techniques etc), it is imperative that we develop methods of information capture, analysis and relay. Such a system should be easily accessible by regional biotechnologists and their inputs obtained. It is noted that in the REDBIO database of LAC biotechnologists, only Cuba (140), Dominican Republic (59) and Puerto Rico (2) have inputted data, probably due in some part to language differences. These language differences will need to be overcome.

Expected results:

- Information system established.
- Socio- and economic database established.

- Database of regional biotechnologists established.
- Prospective analysis of key issues is carried out.

7.3.2 Policy and regulations

Biotechnology and biosafety development go hand-in-hand. It is essential to develop the safety nets for biotechnology by collaboration throughout the region in order to obtain regional standards. Analysis of biosafety practices of other regions needs to be carried out. Also, governments need to be informed of the strengths and weaknesses of biotechnology, and which international agreements need to be adhered to.

Expected results:

- Agrobiotechnology regulations (biosafety, IPR, food safety, technology access) strengthened and harmonized at the regional level.
- Reviews of international agreements provided for decision making.
- Conceptual frameworks for national policies developed.
- Socio- and economic impact evaluated.
- Agrobiotechnology manifesto (strategy and action plan) prepared.

7.3.3 Research and development

Biotechnology, in its complete spectrum, is a complex interaction between the sciences, engineering, computing (IT) and even social sciences, and thus it is very difficult to put forward a biotechnology program without a critical mass of scientists. The countries of the Caribbean are small to tiny and therefore co-ordinated efforts are beneficial, as CARDI has proved in the OECS. The island states of the Caribbean are often competing for the same funds, and require similar training in biotechnology. It is therefore proposed that priorities and a way forward to realize these goals be established. In order to convince governments to invest in agro-biotechnology, the scientists in the region need to decide in what, and how much funding is required to carry out the identified priorities. There are examples of many successful regional projects eg for hot pepper improvement, and these need to be developed further, maybe with help from established North and Latin American programs. Such Caribbean projects should be aimed at developing cutting-edge programs and answering pressing problems at the same time.

Expected results:

- Regional R&D priorities for agrobiotechnology are set.
- Strategy for R&D determined.
- Regional projects formulated and carried out with each Caribbean country participating in at least one of these projects.
- Training in cutting-edge biotechnologies carried out in each Caribbean country according to priorities set.
- Strategic alliances for interregional projects made with Research Cooperative Programs of the Americas (eg PROCIS, REDBIO) and NARS relevant to the Caribbean region.
- Financial support for priority agrobiotechnology R&D projects established.

7.3.4 Capacity building

In order to carry out the proposed research and development, and transfer the developed innovations into the market place, while keeping governments and the general public aware of these developments, requires capacity building. This process has been occurring at a steady pace throughout the Caribbean but efforts are thwarted by duplications, redundancies and lack of sufficient monetary backing. At the same time, there are many initiatives in the Caribbean and elsewhere (eg PROCICARIBE, REDBIO, INFOTEC) on which a lot of time and money has been expended but from which the Caribbean has not benefited except for a few cases, because of lack of knowledge and language barriers. The process of capacity building can be simplified with a regional approach, taking into account the need to strengthen national programs.

Expected results:

- Human resources developed for research, policy making, regulatory activities.
- National programs developed in agrobiotechnology through regional approach.
- Infrastructure for identified agrobiotechnology priorities established.
- Regional reference/certification labs enabled to support biosafety needs.

7.3.5 Commercialization and trade

Biotechnology is the use of living organisms and technology to make products that can be sold. Indeed, many nations of the world that have invested into biotechnology, are now reaping the benefits. It is essential then, that the developed innovations get into the market place, whether they are developed within or without the Caribbean. The first requirement here, is to take an inventory of what is already taking place. Training is required in intellectual properties rights, the need for market surveys and the writing of business plans. Incubator centres need to be established to facilitate the transfer of technology into the market place. Bio-parks need to be established to enable synergy and allow for the reaching of a critical mass of scientists are services. Sharing of information across the region can speed up this process.
Expected results:

- Inventory of biotechnology industries carried out.
- Technology innovation initiatives through partnerships established.
- Innovation incubator centres established.
- Market information made available for agrobiotechnology products.

7.3.6 Education and public perception

Finally, it is essential to inform the public of the uses and weaknesses of biotechnology to ensure safe use of this very useful but still young technology, and also to develop educational guides and programs to ensure the continuity of effort.
Expected results:

- Educational material on agrobiotechnology developed and disseminated for primary, secondary and university programs
- Educational seminars, workshops and courses developed and carried out
- Train the trainer programs for the public perception of agrobiotechnology developed
- Regional education program to disseminate information on agrobiotechnology in the school system established.

7.4 Activities

During the process of building this agenda, specific information will be gathered to outline more precisely the activities that are linked to the expected results listed above based on established priorities.

7.5 General principles

There several principles that needs to guide the agenda. The Agenda will concentrate on regional needs. It will reflect the needs and inputs of the public and private sector, NGO, academic sector and civil society for all countries in the region. It will be guided and developed by sound scientific and technical principles to support of political decisions. Alliances and partnership will be a key method used to drive the agenda. The Agenda will be developed to develop agrobiotechnology in the region while conserving the natural resource base by encouraging the sustainable use of biodiversity. It will encourage the equitable distribution of benefits and will respect everyone's right. It will require the commitment of the countries of the region to be successful.

7.6 Key actors and Stakeholders participation

There are many different groups that need to be involved with developing and carrying out a regional agrobiotechnology agenda. There are several key actors who should be involved. These include regional universities and agricultural institutes, ministries of agriculture and affiliated institutes, and industry. Stakeholders who need to get involved include policy makers (governments), regional and international funding agencies, regional IPR offices and marketing institutions.

7.7 Operational strategy or sequence of undertaking:

a) It is very important to obtain feedback from the different scientists, experts and interested parties in the field of biotechnology (or any other relevant discipline such us biology, medicine and agricultural economics) in the region so that the CGABC would represent regional interest. The following has been the approach to achieve this goal:

- Have a number of regional scientists to meet before REDBIO 2004 to discuss the rationale behind the CGABC and the overall vision for a follow up plan. This step was achieved with the presence of scientists from Jamaica, Trinidad and Tobago, Cuba, Barbados, Dominican Republic and Colombia. This first meeting triggered such a high interest among those present and absent that a second and follow up meeting took place before REDBIO 2004, to continue working on the base document.
- Take advantage of any forum where massive presence of Caribbean scientists and regional key individuals are present to discuss the initiative. Technical meetings such as REDBIO 2004 in Dominican Republic (10 Caribbean countries represented), and the Caribbean Food Crop Society Meeting (virtually all Caribbean countries were represented). In both cases, great discussions took place and the work on the reference document was advanced and deepened. Other regional meetings should be utilized to generate consensus before launching and actually starting the execution of the CGABC's Agenda.
- Use electronic means to make available the discussion paper to as many Caribbean individuals as possible. For obtaining this objective, both sending mails and uploading the document on an advertised website (s) such as IICA, UWI, CARDI and IDIAF web pages.
- This step is set to be accomplished by November 2004.

b) Pursue regional political support, especially in terms of vision, commitment and financial back up. It is essential to convey the message to our governments that biotechnology is important for us in the Caribbean to fight adversity during the next twenty years. Today, this prospect seems not to have aroused the concern it calls for. Haiti is the first victim, yet we do not seem to realize the imminence of a difficult time in front of us, major problems being water scarcity and soil deterioration. To obtain this objective, the following sequence of events ought to be undertaken:

- Promoting biotechnology within the region has been a mandate from CARIFORUM as viewed in the Caribbean Agricultural Development Program (CAFP) funded by the European Union through the LOME IV treaty. However, the great initiative launched by CAFP on biotechnology did not go far precisely because it was lacked a follow up and implementing means such as the CGABC proposed here.
- It is also important to stress that the CGABC has an official and governmental origin. The government of the Dominican Republic, as a way to take advantage of the great venue that REDBIO 2004 represented for the region, asked IICA for support to bring Caribbean scientists before and during the meeting and to work together on a Regional Biotech Agenda and means to execute it. Since then, IICA has backed up the development of the Caribbean Biotech Agenda and the formation of the CGABC.
- An informative letter directed to Governments indicating the major points and rationale behind the CGABC and the Caribbean Biotech Agenda in general. This letter could be sent from IICA, given its leadership role in the initiative. It is expected that IICA's country offices shall follow up on the feedback, provided a timeline.
- Distribute the base document to governments using exactly the same approach as in 2.
- Approach official bodies such as CARICOM and CARIFORUM with initiative.
- In partnership with the region governments, approach extra regional cooperation agencies, initiatives, or programs such as the European Union, FAO, USAID, CIDA, JICA among others.

- Propose a 5 year program with a defined budget (as attached) and with specific and well outlined expected results to agencies listed in 5 through a joint request between IICA (through the CGABC) and one or more of the regional official bodies listed in 4.
- This step was set to be accomplished by November 2004.

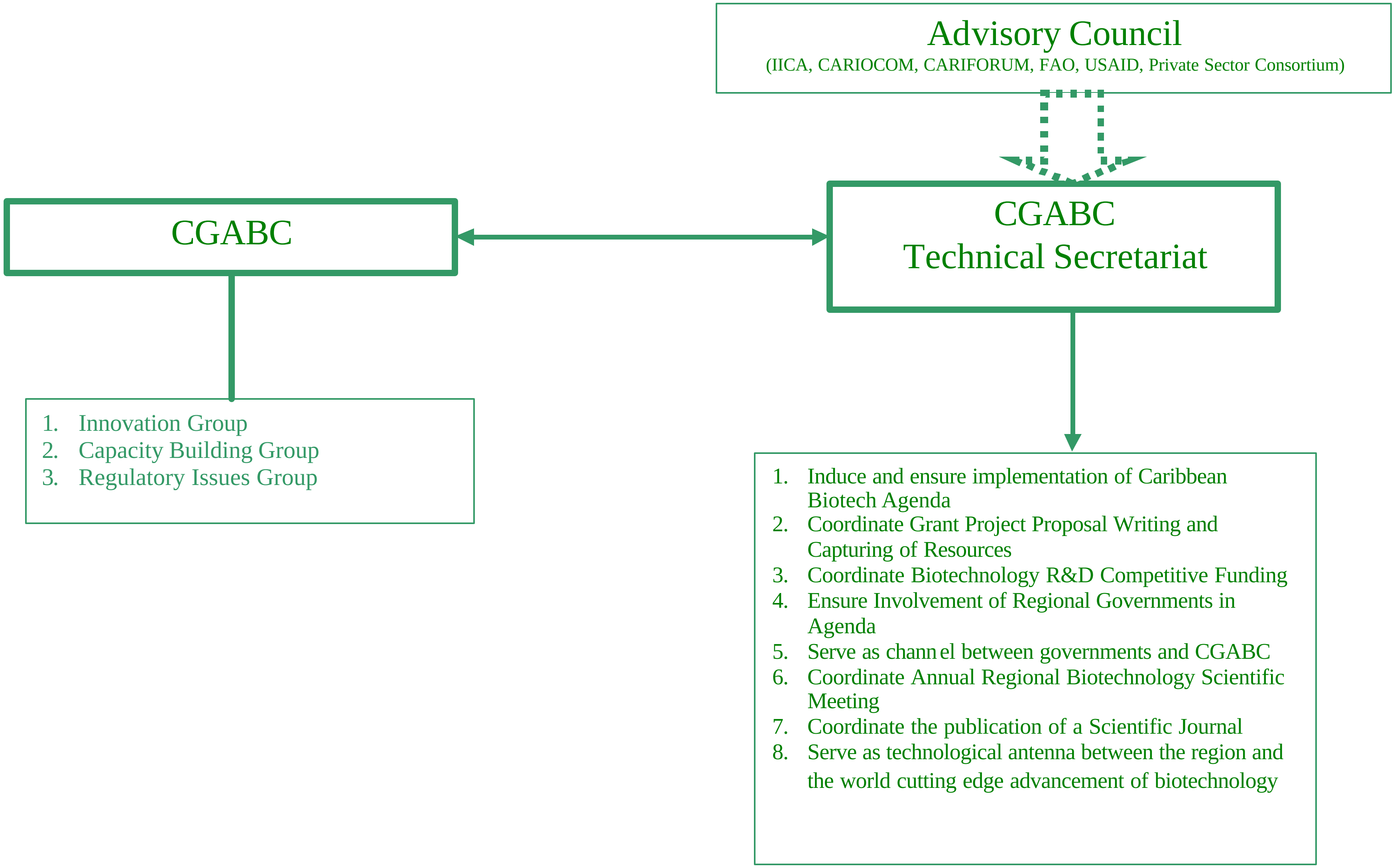
c) This proposed agenda is a platform, a guide, which would facilitate planning. The agenda should be a "known" document, with known goals and themes, a route towards the future with futuristic but practical well-defined expected results. Among the major activities included in the agenda are the following:
  - *Grant Project Proposals.* Major projects should be formulated on key areas both oriented to boost regional agriculture competitiveness and to insert the region within the cutting edge of biotechnology. A minimum of three major regional R&D projects and a minimum of three national projects per country during the next ten years.
  - *Biotechnology R&D Competitive Funding.* A competitive fund of 30 million USD for the next ten years would greatly contribute to creating the capacity within the region. The Fund could be split into a) A portion of the funding should support national applied biotech research and b) A portion of the funding should go into fundamental research on areas such as biofortification, natural product, vaccines, abiotic stress engineering. This fund shall be the result of formal requests from regional governments through the CGABC.
  - *Participation of Region Governments in Agenda.* Region governments, through regional bodies such as CARICO M/ CARIFORUM, give the mandate for agenda implementation. They also should be part of the advisory council of the CGABC. Individual countries should also be assisted in developing and implementing an agenda accordingly with their particular interest in synergy with the overall regional agenda. Key aspects include regulatory framework, technology transfer and training.
  - *Annual Regional Biotechnology Scientific Meeting.* The CGABC Annual Meeting (eg. **Bio-Caribbean 2005**) should be one of the traditions of the CGABC. At the beginning, this effort might be coupled to other regional meetings. Bio-Caribbean should serve as a scientific forum and as a space to discuss collaborative work and networking within the region, in the field of biotechnology.
  - *Publication of a Scientific Journal (eg. BioRadar; BioScope; BioTropical).* The first and the last examples mean the same thing in English as in Spanish. The Caribbean scientific journal with emphasis on biotechnology shall provide scientists from the region with powerful tools and resources to create, acquire, and manage scientific knowledge and to accelerate and enhance their work.
  - *Technological Antenna.* The CGABC should constitute the bridge between the region and the world's cutting edge advancement of biotechnology.

d) Role of national organizations within a regional approach to boost agriculture competitiveness by applying biotechnology. National institutions such as universities, seed companies, national research institutes, science and technology ministries, agriculture ministries and others should be assisted when required in capacity building activities, competitive funding, design and implementation of policies and in the preparation and implementation of any project at the national level, relevant to the achieving of the goals of the national and regional agenda.

e) It is important to understand that synergy is vital among regional relevant organizations and institutions for the successful implementation of the agenda. However, it should not be taken for granted and instead should be well planned for the type of interaction and participation of regional organizations. Major themes such as innovation (CARDI), public perception (REDBIO), training and knowledge transfer (CACHE), technology transfer and dissemination (PROCICARIBE), competitive funding (IICA, FAO, EU, and USAID) should be linked. It is a responsibility of the CGABC secretariat to ensure collaboration and alliances among these parties to help in the implementation of the agenda.

f) During REDBIO 2004, a Project Portfolio was developed. This project portfolio is very relevant for the region since it was the result of workgroup effort with a regional and collaborative perspective. In Appendix 1, a list of potential projects to be undertaken is presented. A database of both national and regional projects will be developed.

<u>CGABC Operational Structure</u>



APPENDIX 1 - PROJECT PORTFOLIO

Title	**Setting the Basis for the Commercialization and use of Biotechnology Products and Services in the Caribbean**
Concept	Difficult international regulatory measures, lack of good quality infrastructure, the dearth of scientific personnel with experience in manufacturing biotech products, ineffective laws relating to Intellectual Property Rights and their enforcement through the Courts and complicated clearance procedures for commercialization of new biotech products are some of the problems faced by the nascent biotech industry in the Caribbean. These problems could be overcome by the industry if Governments from the region put in place industry-friendly policies and simplifies the procedures for various clearances required for commercializing new biotech products or services. Being able to commercialize biotechnology products and services in the Caribbean, including GMOs, it not only opens extraordinary windows of opportunities for business within the region, but also would stimulate innovation, speeding the biotech advancement.
Background	The International Service for the Acquisition of Agri-Biotech Applications (ISAAA) reports that from 1998 to 1999, the global area of transgenic crops increased 44% from 69.5 million to 98.6 million acres. ISAAA further reports that the United States, Argentina, Canada and China grew the majority of the transgenic crops and that the global market for transgenic crops is projected to reach approximately $3 billion in 2000, $8 billion in 2005 and $25 billion in 2010. In view of the importance of regulatory framework in enabling innovation and commercialization of biotechnology products and services, in the Caribbean, the CGABC has to play a proactive role in creating the ambient and awareness throughout the region. The region Governments, assisted by the CGABC should work hard on setting up the data bases on world wide patents, providing patent search facilities for regional and national scientists and entrepreneurs, while creating an awareness of Intellectual Property Rights in the region and an innovative mind set amongst its people.
Scope and timeline	A regional project would include basically all the Caribbean and should be undertaken in a maximum of five years. It is important to understand, also that this type of activities is more effectively implemented if a group of countries decide to work in partnership.
Potential Funding Sources	Private Biotechnology Companies, USAID, National Governments
Countries Involved	All Caribbean countries

Title	Strategy for the management of lethal yellowing of coconut in the Caribbean, utilizing biotechnology
Concept	A regional team of scientists couple effort to approach the problem of the lethal yellowing in terms of developing strategies towards characterizing the problem, diagnostics, prognostics system, propagation of tolerant material and germplasm management.
Background	Lethal yellowing has become a real threat to the Caribbean. Would we imagine the Caribbean without coconut? Would the regional tourism industry survive without coconut?, Maybe, but we do not know how long would it take for our islands to recover from such a catastrophe. There are already examples. Honduras is facing real difficulties with their tourism industry, and so is Jamaica. Provided this scenario and aware of the socio-economic consequences of the continue evolution of the lethal yellowing of coconuts in the region, a group of scientists gathered at REDBIO2004 to discuss the problem as a region. Scientists from Mexico (CICY), Jamaica (CIB), Honduras (Zamorano), Dominican Republic (IDIAF) and Cuba (IIFT) discussed the prospect of a regional effort through a Technical Cooperation Project that would support a regional research project. An amplified research proposal is underway.
Scope and timeline	A regional project would include basically all the Caribbean and extra regional counterparts such as Mexico and Honduras. A regional project of this nature and of this importance should be undertaken in a maximum of five years. It is important to understand, however, that this problem requires continuous work and vigilance, thus the effort has to be at a long term one.
Potential Funding Sources	FAO, FONTAGRO, EU, Private Tourism Companies and coconut processing and export companies
Countries Involved	Dominican Republic, Jamaica, Cuba, Trinidad & Tobago, Puerto Rico, Mexico and Honduras

Title	**Establishing Regulatory Framework within the Caribbean to Boost Agriculture Competitiveness, utilizing biotechnology**
Concept	Both at a national and regional level, there should be regulatory bodies to deal with issues related to intellectual property, biosafety, food safety and differentiated agriculture (organic agriculture) adequately implemented that would facilitate the exploitation of biotechnology, as a means to enhance agriculture competitiveness.
Background	Most of Caribbean countries lack regulatory systems for genetically modified (GM) and other novel organisms. The region therefore is not adequately prepared to take advantage of the increasing new biotechnologies, products and services being developed around the world. These biotechnologies include a great deal of genetic engineering advances available in other parts of the world. While there has been a significant progress in terms of investment and biotechnology research in some countries such as Cuba, Jamaica, Trinidad and Tobago and Dominican Republic, the regulatory system has not evolved at the same speed to handle the risk analysis of the resulting products. If the Caribbean countries do not act quickly on establishing regulatory frameworks within the region, countries would not gain the benefits of these new technologies and products, while the economic loss could ultimately stall other socially desired research and development in the region.
Scope and timeline	Biotechnology and biodiversity regulatory framework should be implemented in each country, accordingly, within a regional context. During the next three years, at least those countries more advanced in their national biotechnology programs, should have their Biosafety Commission and the corresponding supporting laws. These countries include Jamaica, Cuba, Dominican Republic, Trinidad and Tobago, Barbados, Belize and Guyana.
Potential Funding Sources	PNUMA, FAO, EU, UNEP-GEF, National Governments
Countries Involved	Jamaica, Cuba, Dominican Republic, Trinidad and Tobago, Barbados, Belize and Guyana.

Title	The Bio -Station Project in the Caribbean: Biotechnology, from Laboratories to the Farm
Concept	Farmers of the region, either in group or individually establish bio-stations for the production of *vitro* plants, biopesticides, bio fertilizers, bio plant regulators, fermented fruit beverages among others as a way of utilizing biotechnologies to improve their welfare. The CGABC assists countries to establish these bio-stations accordingly.
Background	Assisting farmers to achieve sustainable livelihoods and prosperity is one of the most imperative challenges facing the Caribbean region at the outset of the 21st century. Though there are many upward pathways to attain this goal, each entails an arduous journey with obstacles or difficult choices at every turn. Bringing biotechnology into the farm and making farmers our partners seem to be a feasible and expeditious route toward making agriculture a much more rewarding activity for those who live their lives at the farm. Farmers in the region are eager to be part of this journey. Working along side with farmers to use biotechnology as a development tool is much more effective to obtain a more sustainable and competitive agriculture, healthy agro ecosystems, and farmer oriented innovations. A great deal of applications is available that could be exploited by farmers themselves such as tissue culture, biological control techniques, fermentative biotechnology and organic agriculture.
Scope and timeline	Provided the resources and national government support, within the next five years, 90% of all Caribbean countries should have at least one bio-station handled by a group of farmers and producing bio-products as input for their production systems. Of particular interest is the production of organic agriculture inputs so the region would maximize its potential in supplying premium organic fruits and vegetables to the US and EU markets.
Potential Funding Sources	FAO, EU, National Governments, The Ford Foundation, The Rockefeller Foundation, United States Agency for International Development (USAID), United States Department of Agriculture, The Wallace Foundation, W.K. Kellogg Foundation, World Resources Institute, The World Bank National Science Foundation.
Countries Involved	All Caribbean countries.

<table>
<tr><td>Title</td><td>The Caribbean Biotech Park</td></tr>
<tr><td>Concept</td><td>
The Caribbean Biotech Park consists of ready-to-use laboratory facilities on a lease basis to regional and extra regional companies and provides support services in the field of biotechnology and related areas. The biopark is linked to academic entities to guarantee the development of human resources and innovations that would induce an expected scientific and technological spill over. The country (s) interested in establishing the BioPark shall provide high quality infrastructure at a reasonable cost with integrated services to biotech manufacturing units.
The Biotech Park aims to provide world-class services to the clients in terms of :

State-of-the-art infrastructure;
One-Stop-Services;
Quality products and services at competitive cost;
Database on availability of skilled professionals;
Networking between research and academic institutions and industry.

The advantages of the Park are visualized to:

Provide a thrust to areas of prioritized industry segments;
Help achieve regional and global leadership in the chosen areas through sharp focus;
Allow for midstream corrections in the subsequent phases of development;
Reduce the capital outlay for entrepreneurs.
Improve the rate of return on investment.

</td></tr>
<tr><td>Background</td><td>
The business side of biotechnology is one of the fastest rate of growth business in the world, right now. Up to 2003, there were 4,300 biotechnology companies in the world. There is a global trend toward the creation of scientific and industrial biotechnology parks to maximize efficiency and profit. Ninety percent of these companies are in US and Europe. However, several developing countries are also getting into the business through the establishment of bio-industrial parks. India generates $5,000 million from biotech related activities and was the first developing country to establish a biopark as a business platform for occident companies. One million people work in the biotechnology business today, in India.
China invested $180 million (1996-2002) to encourage the biotech industry. Between 2002 and 2005, China has projected to invest $524 millions. Singapore owns one of the most successful biopark in the world (Biopolis, with 1.7 billion investment). Uruguay has the first Latin Biopark (Zonamerica) which generates $1,500 million per year to the country of Uruguay.
</td></tr>
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	While US obtains 70% of all benefits derived from biotechnology and Europe 20%, in the Caribbean we are still expecting to be convinced that biotechnology can certainly enhance our chances of improving our standard of living.
Scope and timeline	An ambitious and futuristic project as the Caribbean Bio Park, cannot be expected to be established in each country in the Caribbean. A geographically strategic country (Cuba, Dominican Republic or Jamaica) can host the installation of the park. All Caribbean countries, however, should be part of this endeavour and the conditions should exist so all Caribbean countries participates either by establishing business or by being tied to the park through the academic, scientific and technological sides. This project should be implemented during the next 5 years (2010). This opportunity could otherwise be taken advantage of by any close country bordering the region such as Panama, Costa Rica, San Salvador, Venezuela, Colombia, Mexico.
Potential Funding Sources	FAO, EU, National Governments, The Ford Foundation, The Rockefeller Foundation, United States Agency for International Development (USAID), United States Department of Agriculture, The Wallace Foundation, W.K. Kellogg Foundation, World Resources Institute, The World Bank National Science Foundation.
Countries Involved	All Caribbean countries

Potential Donors

CARIBBEAN Countries	CARICOM CARIFORUM
Regional Cooperation Organization	IICA
Australia	Australian Agency for International Development Australian Centre for International Agricultural Research
Belgium	General Administration for Cooperation in Development (AGCD)
Brazil	Brazilian Agricultural Research Enterprise
Canada	Canadian International Development Agency International Development Research Centre
Denmark	Danish International Development Assistance European Union Food and Agriculture Organization of the United Nations
France	Center for International Cooperation in Agricultural Research for Development Institute of Research for Development National Institute for Agricultural Research
Germany	Federal Ministry of Cooperation and Economic Development German Agency for Technical Cooperation Inter-American Development Bank International Fund for Agricultural Development
Italy	Ministry of Foreign Affairs
Norway	Norwegian Agency for Development Cooperation
Spain	International Agency for International Development of Spain
Sweden	Swedish International Development Agency
Switzerland	Federal Institute of Technology Development Swiss Agency for Development and Cooperation Swiss Centre for International Agriculture
Unit ed Kingdom	Department for International Development Natural Resources Institute United Nations Environment Programme
United States of America	The Ford Foundation The Rockefeller Foundation United States Agency for International Development (USAID) United States Department of Agriculture (USDA) The Wallace Foundation W.K. Kellogg Foundation World Resources Institute The World Bank National Science Foundation

8.0 FRAMEWORK OF THE CONSULTATIVE GROUP FOR AGRICULTURAL BIOTECHNOLOGY IN THE CARIBBEAN (CGABC)

In order to accomplish the agenda as outlined in this discussion paper, a mechanism has to be developed[27]. Outlined below is a preliminary framework for a Consultative Group for Agricultural Biotechnology in the Caribbean (CGABC). This consultative group has specific objectives to assist in achieving the agenda.

8.1 Nature

The CGABC is conceived as having several characteristics. It will have an Advisory/Consultative role. It will promote the use of biotechnology in the region as it applies to agriculture (crops, forestry products, animals, fisheries). It will provide a mechanism to enhance the capacity of the region of agrobiotechnology by developing networks and by building capacity.

8.2 Principles

The CGABC is guided by several principles. It will encourage the development of sustainable and safe uses of biotechnology to generate prosperity. It will provide a mechanism for long-term planning. It will lobby government to encourage the use of biotech in agriculture. It will provide advice to governments that is technically based. It will independent and non-partisan but useful to regional government. It will work for the best interest of the Caribbean people. It will take advantage of this technology to enrich the lives of West Indians.

8.3 Purpose

The CGABC will have an advisory role but will also promote and enhance the use of biotechnology in the region. It will be an active group of antagonists that will help to develop the science and the scientists.

8.4 Goal

To serve as technological and scientific support mechanism for the advancement of agricultural biotechnology in the Caribbean Region to improve the welfare of people and safeguard our biodiversity in a proactive and sustainable way.

8.5 Objectives

- To assess the present (international, regional and local) status of agriculture and rural development from a biotechnology perspective
- To monitor and discuss policies on agri-biotechnology and repackage them for the Caribbean
- To foster co-operation among stakeholders
- To encourage dialogue among stakeholders in respect of the role of biotechnology
- To assist countries in the capacity building process in biotechnology and biosafety, priority setting and regulatory framework.
- To advise countries on how to develop the institutional environment to take advantage of biotechnology for better use. (Human capacity – training, critical mass, Infrastructure, Legal regulatory framework)
- To strengthen Caribbean negotiations by providing advice on market and trade related issues
- To provide a mechanism to mobilize solutions by linking those that have problems to those that have solutions.

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[27] An example of a similar network in the Caribbean that is successful is the Caribbean Coastal Marine Productivity program (CARICOMP) - a regional scientific program and a network of marine laboratories (see Table 9)

- To facilitate linkages between the Caribbean and the rest of the world
- To provide a forum for interaction on policies related to biotechnology
- To provide suitable information and technology capture and dissemination
- To assist regional governments to establish sound biotechnology p olicies
- To help to set priorities in terms of agro-biotechnology
- To promote public awareness of agro-biotechnology in the Caribbean
- To enhance innovation and technology transfer
- To identify and encourage agro-biotechnology business ventures

8.6 Scope

The CGABC geographically includes all the Caribbean island states, and those surrounding countries that are in CARICOM – Belize, French Guiana, Suriname and Guyana. It will address only those biotechnologies that can be applied to agriculture.

8.7 Clientele

By providing a consultative role, the CGABC will serve the Public sector – government, schools etc, the Private sector – farmers etc, Academia and biotechnology professionals, NGOs, Civil society, Regional organizations and the International community.

8.8 Composition

The CGABC will be composed of individuals with technical and scientific capability in R&D, Management, Fundamental and Applied Science, and political science. It will utilize experts in different facets of biotechnology who are well respected professionals. It will have external advisors (in R&D management, Biosafety, Public perception, Scientists, Bioregulation (IP), Bioinformatics, Business and Economics, Public relations, and Trade). The composition of the CGABC will reflect the vast experience of the Caribbean professionals in agrobiotechnology and will rotate among the countries of the Caribbean to maximize its effect. The core of the CGABC will be a small committee of 8-10 people on a rotational basis for short office terms. Technical panels will be assembled as needed (demand driven committees).

8.9 General Activities

The activities of the CGABC will include mechanism for forums, E-newsletter, information gathering and dissemination, idea gathering, Activities/Projects, Consultancy/advisory activities. The following umbrellas of activities are envisaged: Tissue culture, Diagnostics, Genetic Engineering, Biodiversity, Bio-regulation, Industrial Biotechnology, Policies, Capacity building.

8.10 Operative/Functional Structure

A small core group including a President, Vice-President, Treasurer and Secretary will execute the mandate and orientate the activities. These will all be paid positions, for short durations and will rotate around the islands and countries of the Caribbean region. The individuals in the core group, or at least the President, will need diplomatic status. There will be an Executive Secretariat, Technical advisory panels – assembled as needed for definite projects, Regional projects – inventory, and priority regional projects and Associate members – in a network – with mechanism to get ideas into the system.

8.11 Suggested projects

- Development of a regional agenda for agricultural biotechnology
- Implementation of biosafety on a regional scale
- Annual report on the status of agr icultural biotechnology in the Caribbean
- Regional project attached to issues eg fruit fly, genome project for hot pepper
- Determine the role biotechnology will play in the region in light of FTAA
- Analysis of international biotechnology issues

8.12 Cost reduction strategies

It is estimated that just to operate the CGABC will take US $ 100-150,000 per year. This includes one or two meetings a year but before projects are even developed. Technical cooperation with regional entities will be developed eg IICA, CTA, EU, UNIDO, REDBIO. A financial plan will be developed. A practical approach is needed to impress on funding agencies the need for such a consultative group to enable the region to reap the benefits of biotechnology as some of the region's countries have already begun to do. Full use will be made of information technology to maximize the impact of the CGABC on regional development.

8.13 Tactics for implementation

The first task for the implementation of the regional agenda on agrobiotechnology was to formulate a mechanism to accomplish this. The result of this first task is the formulation of a proposal for a consultative group (CGABC) as outlined in this document. This document is a discussion paper designed to present the needs and the opportunities in order to build consensus on the way forward.

By a consultative process with key national and regional stakeholders, endorsement of this agenda is sought at a regional level in order to have a regional platform for implementation (institutional support). There needs to be regional cooperation endorsement and regional government commitment. The support of private agri-businesses will be sought and cost recovery systems (patents, tax, licenses, royalties) will be established. The agenda can then be dissemination and executed.

APPENDIX 2

Figure 1 GMO crops world-wide in 2003

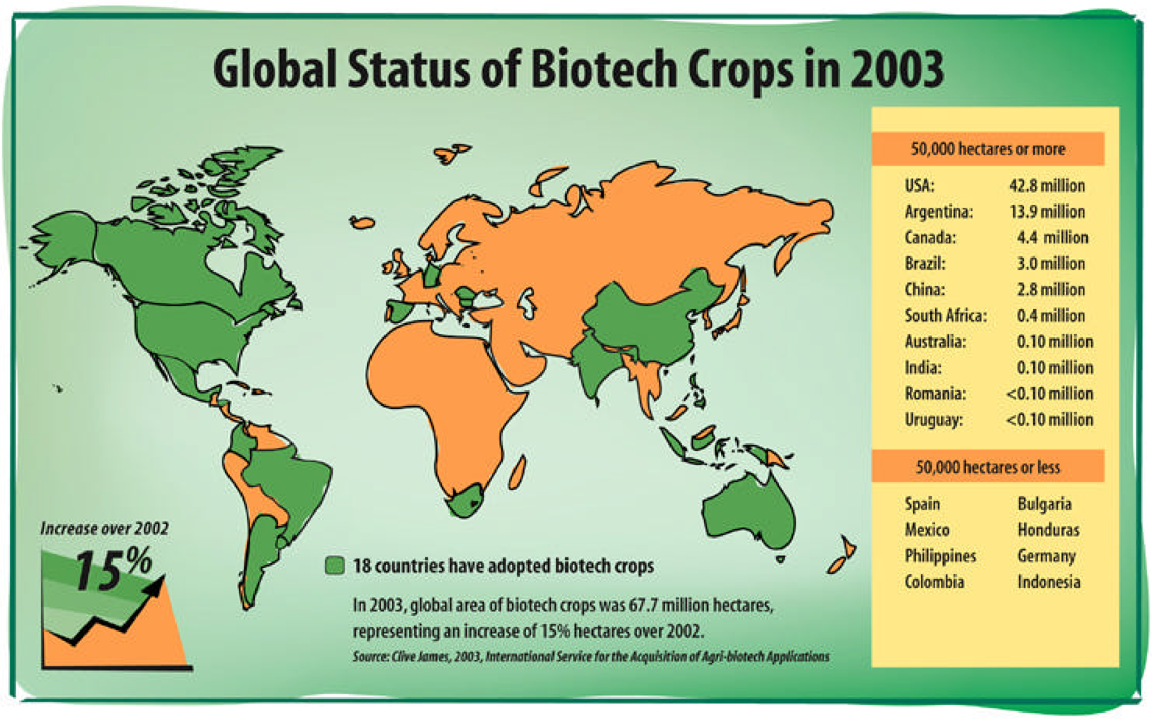

Table 1. Key economic indicators for 29 Caribbean regional countries

Country	*Highest point (m)*	*Coast-line (km)*	*GDP per capita in 2001 (US$)*	*GDP agric-indus-service*	*External debt (US$ Million)*	*Trade balance Exports/ Imports*	*Internet users as percentage of population*
Anguilla	65	61	8,600	4-18-78	8.8	0.03	7
Antigua and Barbuda	402	153	10,000	4-19-77	231	0.11	7
Aruba	188	68	28,000	NA	285	0.99	34
Bahamas	63	3,542	16,800	3-7-90	382	0.28	6
Barbados	336	97	14,500	6-16-78	425	0.23	2
Belize	*****						
Bermuda	76	103	34,800	1-10-89	145	0.07	39
British Virgin Islands	521	80	16,000	2-6-92	36	0.03	NA
Cayman Islands	43	160	30,000	1-3-95	70	0.003	NA
Cuba	2,005	3,735	2,300	8-35-58	27	0.38	1
Dominica	1,447	148	3,700	18-23-59	150	0.37	3
Dominican Republic	3,175	1,2888	5,800	11-34-55	240	0.63	2
French Guiana	******						
Grenada	840	121	4,750	8-24-68	196	0.29	6
Guadeloupe	1,484	306	9,000	15-17-68	NA	0.08	0.9
Guyana	******						
Haiti	2,680	1,771	1,700	30-20-50	1,200	0.33	0.4
Jamaica	2,256	1,022	3,700	7-28-65	5,200	0.52	4
Martinique	1,397	350	11,000	6-11-83	180	0.12	1
Montserrat	914	40	2,400	5-14-81	8.9	0.06	NA
Netherland Antilles	862	364	11,400	1-15-84	1,350	0.18	0.9
Puerto Rico	1,338	501	11,200	1-45-54	NA	1.43	15
St Kitts-Nevis	1,156	135	8,700	4-26-71	140	0.37	5
St Lucia	950	158	4,400	8-20-73	214	0.21	2
St Vincent and the Grenadines	1,234	84	2,900	10-26-64	167	0.29	3
Suriname	*******						
Trinidad and Tobago	940	362	9,000	2-43-55	2,200	1.17	10
Turks and Caicos	49	389	7,300	NA%	NA	0.08	NA
US Virgin Islands	474	188	15,000	NA%	NA	$NA	10
USA	6,194	19,924	$36,300	2-18-80	$862,000	0.63	59

Source: CIA World Factbook 2002 http://www.odci.gov/cia/publications/factbook/print/jm.html

Table 2 Agricultural Research Expenditures Relative to Agricultural GDP and Total Population, 1996

Country	Agricultural research expenditures (million 1993 PPP$)	Agricultural GDP (million 1993 PPP$)	Agricultural research intensity (%)	Total population (thousand)	Agr. research expenditures per capita (1993 PPP$)
Anguilla	0.000	3.6	0.00	8	0.00
Antigua and Barbuda	0.577	19.6	2.94	66	8.74
Aruba	0.125	14.1	0.89	71	1.76
Bahamas	3.095	86.5	3.58	284	10.90
Barbados	2.559	152.3	1.60	261	9.80
Belize	1.762	160.1	1.06	219	8.05
British Virgin Islands	0.122	5.9	2.07	19	6.44
Cayman Islands	0.000	10.1	0.00	32	0.00
Cuba	NA	NA	NA	11,018	NA
Dominica	1.356	52.5	2.58	71	19.09
Dominican Republic	9.210	4,439.5	0.21	7,961	1.16
French Guiana	8.533	NA	NA	153	55.77
Grenada	1.223	31.1	3.94	92	13.30
Guadeloupe	13.169	224.9	5.86	431	30.55
Guyana	8.634	702.0	1.23	838	10.30
Haiti	NA	NA	NA	7,259	NA
Jamaica	7.916	709.7	1.12	2,491	3.18
Martinique	3.700	217.8	1.70	384	9.64
Montserrat	0.000	2.8	0.00	11	0.00
Netherlands Antilles	0.000	21.2	0.00	195	0.00
Puerto Rico	15.518	415.9	3.73	3,736	4.15
St. Kitts and Nevis	0.523	13.3	3.92	41	12.75
St. Lucia	0.709	56.9	1.25	144	4.92
St. Vincent and the Grenadines	2.608	46.9	5.56	113	23.08
Suriname	0.662	215.2	0.31	432	1.53
Trinidad and Tobago	12.357	148.4	8.32	1,297	9.53
Turks and Caicos Islands	0.000	NA	0.00	15	0.00
Virgin Islands (U.S.)	1.965	NA	NA	106	18.54
Regional total / average [a]	95.799	7764.6	1.23	19,471	5.43

Sources: AgGDP: World Bank (1999a), ECLAC (1998), and CIA (1999); Total population: FAO (1999) and CIA (1999).
[a] Regional total / average in columns 1, 4, and 5 covers 26 countries (all Caribbean countries except Cuba and Haiti), while columns 2 and 3 cover only 23 countries due to lack of AgGDP data for three countries.

Table 3 Brief status of agricultural biotechnology in five of the larger Caribbean island states

Country	Crops	Biotechnologies	Investment	Questions
Dominican Republic	Banana – 60-80%, Plantain Potato Ornamentals Coffee Forestry species Garlic Cacao Roots and tubers Avocado – molecular markers	Fermentation – sugar cane to ethanol, cheese Plant biotech –production capability of 2-3 million micropropagated plantlets/yr Production of bio-pesticides – Trichoderma, inoculants (N fixation), production by fermentation Extraction of plants – peppers and native plants Vaccines and diagnostics for animal diseases Value-added projects – eg lactic acid production	IDIAF– 20 projects 2 other major labs 10-12 smaller labs (most plant m-prop) 2 labs Vaccines – rabies etc Diagnosis for TB Biotechnology personnel – rough figure – ~30 (PB) ~ 10 (AB), ~20 (Diagnostic) 12 labs No GE as do not have facilties	There is an ad hoc regulatory commission and a legal package is being prepared to regulate biotechnology activities and biodiversity. Still the country is not member of the Cartagena Protocol. The understanding exists that unless all details related to this protocol are studied, signing the protocol is not convenient even when benefits could be derived such as accessing funding and external resources.
Barbados	Yam Hot pepper Plantain Banana Orchids	Micropropagation. PCR, fingerprinting – sheep, yam, hot pepper No GE but have done it in the past, make transgenic tobacco as teaching exercise Extracts from plants – Canadian lab (some conflict) – need to sign who will have patents	< 100,000 plantlets 2 major, one minor labs 12 people need – Banana tc – US $ 1 each	Temp of GE – influenced by European opinion No regulation in place but encouraging this. IP laws in place but no one is using it nationally UNEP/GEF – National biosafety framework
Cuba	Sc Banana Plantain Potato	Transformation – Banana, Plantain against black sigatoka, Sugar cane resistant, Potato – fiber, resistant to insect, pineapple resistant to fusarium, papaya resistant to ring spot virus	25 m plantlets per year (80% banana, potato) 15 laboratories $ 5 mill investment 15 people in one institute	Transgenic plants not in field, only in the lab No GE in the field Regulation in biosafety in place IP in place
Jamaica	Banana Plantain Ornamentals – anthuriums, orchids Medicinal plants – neem Hot pepper Ginger Yam Papaya	Gemini virus – Molecular biology and transformation of tomato Hot pepper – molecular markers Molecular biology – AFLP – ginger, other med plants Micropropagation Somatic embryogenesis Transgenic plants – papaya solo resistant to RSV Livestock – embryo transfer Inoculants – VAM – legume Composting Bio-pesticides Xanthum gum from fermented molasses Biodigesters Perception problem - mutation	Biotechnology Centre Molecular Biology Building Biochemistry Dept Microbiology section NPI SRC Orchid tc labs	Temp of GE – influenced by European opinion A regulatory oversight committee in place and regulations being developed. Organic farming – tissue cultured plantlets allowed IP laws in place – only a few patents so far in science, none in biotechnology. Patents – spirit weed, ganja –canasol – glaucoma. We do not own many patents on work done UNEP/GEF – National biosafety framework Market against GE crops
T&T	Anthurium Cacao Hot pepper Gingerlilies Roses Orchids	Transformation – anthurium – flower color, bacterial resistance; cacao – agrobacterium transformation; banana – resistance to *Fusarium* Gemini virus – molecular and biological characterization Hot pepper – genetic diversity, viral resistance, capsaicin	?	Biosafety committee

Table 4 Biotechnology practices in the Caribbean

- Production of mushrooms (Ja)
- Tissue culture (commercial and semi-commercial ventures): Anthurium, banana, plantain, pineapple, ginger, yam, medicinal plants including neem, gingerlilies, roses and orchids (many)
- Development of a banana (*Musa* spp. AAA Group) plant resistant to *Fusarium oxysporum* (f.sp. *cubense*) using mutagenesis (T&T)
- Development of anthurium lily (*Anthurium andreanum*) with increased resistance to bacterial infection (including *Xanthomonas* and *Pseudomonas*) using transformation methods and somatic embryogenesis (T&T)
- Determination of the biochemical pathway of colour in anthuriums, and disease tolerance. The technology has been applied to flower growers in T&T exporting to Holland (T&T in collaboration with Crop and Food Research, New Zealand)
- Transgenic resistance of *Anthurium andreanum* to bacterial diseases (T&T)
- Characterisation of *Capsicum chinense* (hot pepper): Genetic Diversity, Viral Resistance and Capsaicin content (T&T)
- Agrobacterium transformation of Theobroma cacao (T&T)
- Screening methods and the genetics of resistance to Witches Broom Disease in cacao (Theobroma cacao L.) (T&T)
- Molecular & biological characterisation of geminiviruses in Trinidad. (T&T)
- Development of tissue culture regeration systems for tropical crops including banana, breadfruit, pawpaw, pineapple, carambola, heliconia, anthurium, orchids to allow for mass propagation of disease-free planting material (T&T)
- Development of microbial sprays for control of ticks and insect sprays (T&T)
- Bioengineering of gut-inhabiting bacteria to improve digestibility of forage in ruminants (T&T)
- Development of new foods, enzymes and industrial chemicals using fermentation technology (T&T)
- Production of citric acid from molasses (many)
- Use of AFLP to generate DNA fingerprints of many important medicinal plants including hot pepper and ginger (Ja)
- Development of a transgenic solo papaya resistant to ring spot disease (Ja)
- Cloning and sequencing of gemini virus genes (Ja)
- Identification of Gemini-viruses of the region, their host plants and vectors (Ja)
- Development of transgenic hot pepper and tomato resistant to Gemini viruses (Ja)
- Biochemical and Microbiological Evaluation of Neem Oil Based Products (Ja)
- Production of Xanthum gum from fermented molasses (Ja)
- Use of VA mycorrhyzae to increase vegetable and legume crop yield (Ja)
- Biodigestors for fuel (methane) production (Ja)
- SRC stores a number of accessions in its Tissue Culture Laboratory (Ja)
- Somatic embryogenesis of woody medicinal plants (Ja)
- The effect of transgenic *Carica* papaya on rats (Ja)
- Biotechnology in Livestock Production: Embryo Transfer Technology and Molecular Genetic Analysis (Ja)
- Molecular Changes associated with developmental processes in yams (Ja)
- Evaluation of *Carica* sp. for resistance to Papaya Ringspot Virus (Ja)
- Biological & Molecular characterization of Papaya Ringspot virus (type-p) isolates from Jamaica (Ja)
- Biochemical analysis of tuberization of *in vitro* derived yam plantlets (Ja)
- Random Amplified Polymorphic DNA (RAPD) Analysis for genetic relatedness and cultivar identification of Jamaican Yams (Jamaica & Germany)
- Screening and Metabolic Analyses of ingestion of Yam Natural Products in animal models (Ja.)
- Molecular Characterization of Cocoyams and Dasheen (Ja.)
- Development of am improved microproagation system for D. cayenensis and D. trifida (Ja)
- Acclimatization of tissue culture-derived yam plantlets and some enzyme changes (Ja.)
- Biochemical index for assessing efficacy of hardening process (Ja.)

- Glycemic Indices of some Yams and other commonly eaten Caribbean foods (Ja.)
- Some biochemical transformations associated with in vitro propagation of yams (Ja.)
- Development of salt/drought adaptation in invitro Greater yam (*Dioscorea alata*) plantlets (Ja.)
- Scanning Electron Micrographs of Yam Starches and industrial applications (Ja.)
- Analyses of Sweet Potato Phytates and metabolic effect of consumption of Sweet Potato Phytate Extract in rat models (Ja.)
- Screening of commonly eaten foods in the Caribbean for antinutritional factors (Ja. & Mexico).
- Microbial interactions between rhizobia and VAM fungi and VAM fungi for nodulation and growth of cowpea (*Vigna unguiculata*) (Ja)
- Recycling agricultural wastes for the production of animal feed and organic fertilizer (many)
- Biopesticide production (many)
- An early accomplishment of CARDI in the 1970's was the development in Barbados of virus-free (internal brown spot) White Lisbon yam by using meristem-tip culture. Exportable yields increased by 40%. (Ba)
- CARDI stores a number of accessions in its Tissue Culture Laboratory in Barbados. These include: forage legumes, root crops, vegetable crops, fruit crops, cereals, and ornamentals. (Ba)
- Identification and development of several disease resistance genes in varieties of pepper and tomato (Ba and OECS)
- Cuba maintains about 18,688 accessions in its *ex situ* genebanks (active field genebanks, traditional seed genebanks, *in vitro* collections and in cryopreservation). (Cuba)
- Propagation and sale of pineapple and plantain tissue cultured plantlets (Guyana)
- Acquire, characterize, evaluate, conserve, document and make available genetic diversity of selected agricultural crop species both in-situ and ex-situ. (Guyana)
- Introduce, Increase, Evaluate, and Enhance Sorghum Germplasm (PR).
- Development of Tropical Fruit Production Systems (PR).
- Introduction, Increase, Maintenance, Evaluation and Distribution of Cacao Germplasm (PR).

Table 5 CARICOM countries with tissue culture laboratories – crops propagated and qualifications of staff therein. *Note: Bahamas, Belize, Haiti and Suriname were not considered.*

Country	**Weaning facilities**	**# labs**	**Crops propagated**	**Tissue culture staff in country**				
				Ph.D.	**M.S.**	**B.S.**	**Other**	**Total**
Antigua	-	-	Pineapple, banana	-	1	-	-	1
Dominica	Yes	-	-	-	-	-	-	-
Grenada	Yes	1	Banana 10,000 Plantain 10,000 Pineapple 40,000 Anthurium 9,500 Orchid 15,200 Tannia 8,100 Yam 4000 Dasheen 7,350 Rose 3,145	1	1	1	7	10
St. Lucia	Yes	1	Anthurium (6) 3,000 orchids (5) 5,000 banana (4) ferns (6) 1,000 yam (8) 2,000 African Violet 25 mushroom	-	1	-	2	3
St. Vincent	Yes	1	Pineapple 10,000 Banana 55,000 Yam (3) Dasheen 2,000 Cassava (25) Orchid	-	1	1	6	8
St. Kitts and Nevis	-	-	-					
Montserrat	-	-	-					
Barbados	Yes	2	Banana 3,000, Plantain 5,000 Anthurium Yam Plantain Banana Orchids	1	2	1	4	8
Jamaica* • Gene bank at SRC has in vitro cultures of over 94 economically important plant varieties.	Yes * UWI lab has over 14 plant varieites	2	Banana 39,000 Plantain 10,780 Ginger 4,480 Anthuriums 1,000 Orchids 400 Neem Pineapple 500 Yam, Papaya Ornamentals mushroom	5	0	2	7	14
Trinidad and Tobago	Yes	2	Anthurium Gingerlilies Roses Orchids	?	?	?	?	?
Guyana *Figures in brackets () is number of accessions*	Yes	1	Pineapple 5000 Banana (4) Plantain 7000 Sweet potato (16) Yam (2) Native species for pesticidal activity (14)	1			2	3

Table 6 Past and On-Going Research Projects At UWI-SA

Agricultural biotechnology

- Development of tissue culture regeneration systems for tropical crops - banana, breadfruit, papaw, pineapple, Carambola, Heliconia, Anthurium, Orchids, Bromeliads.
- Development of transformation systems to bioengineer tropical crops- Cocoa, sugarcane, tomato, anthurium.
- Isolation and characterisation of genes - Flavanoid biosynthetic genes from anthurium, Abscission related genes in pigeonpea, Starch biosynthetic genes from Yambean.
- Bioengineering tropical plants - Augmenting the colour range in anthurium, Improving resistance to geminiviruses in tomato and pepper.
- Bioengineering bacteria - Bioengineering *Acidovorax* and *Xanthomonas* with gfp gene to monitor systemic spread of the pathogen in anthuriums, Bioengineering gut-inhabiting bacteria to improve digestibility of forage in ruminants.
- Diagnosis of tropical diseases & other pests using molecular biological techniques - geminiviruses and potyviruses affecting tomato and pepper, *Ralstonia solani* (bacterial wilt) affecting tomato, banana, heliconia, *Acidovorax anthurii* (bacterial spot) and *Xanthomonas campestris* pv. dieffenbachiae affecting anthuriums, *Xanthomonas campes*tris affecting cabbage, whiteflies in Tomato, Blackpod and Witches' Broom diseases of cacao. Johnson, L and Butler, D. Cocoa Research Unit.
- DNA Fingerprinting cultivars and varieties for identification (Intellectual property) – Cocoa, Pepper
- Biotechnology in the assistance of breeding, by developing molecular marker maps - Molecular markers (QTLs) have been determined for *Phytophthora* (Black pod disease) resistance in cacao and is being developed for Witches broom disease, towards accelerating the breeding for resistance to these important diseases.
- Microbial pesticides - use of microbial pesticidal sprays to treat diseases, insects - Use of microbial sprays against ticks, Use of *Bacillus thuringensis* as pesticide, Control of Sugarcane frog hopper damage using metarhizium, Use of microbial pesticides against seed weevils in legumes.
- Improving Biological N-fixation using microbial biotechnology - pigeonpea.

Environmental biotechnology

- Molecular genetic diversity of indigenous forest species in national parks towards developing conservation strategies.
- Plant genetic resources conservation - determining the molecular genetic diversity of indigenous landraces and determining collection strategies - Hot pepper germplasm, Breadfruit germplasm, Endemic Medicinal Plants
- Biodiversity of tropical Marine and Freshwater fishes.
- Cleaning Oil Spills using microbial biotechnology
- Bioremediation of Poly Aromatic Hydrocarbons using microbial biotechnology

Industrial biotechnology

- Fermentation biotechnology - Developing new foods, enzymes and industrial chemicals using fermentation technology; identification of micro-organisms.
- Development and modification of process parameters

Medical biotechnology

- Genetic characterisation on maturity onset diabetes in Trinidad and Tobago.
- Molecular characterisation of dengue subtypes towards better management of dengue epidemics.
- Molecular characterisation and subtyping rabies isolates in Trinidad and Tobago
- Analysis of polymorphic human response genes.

Table 7 Some High Impact Agro-Biotechnology Projects in UWI-SA

CASE-1: DEVELOPING ANTHURIUMS ADAPTED TO THE HUMID TROPICS

Anthurium is becoming a major export crop in Trinidad and Tobago. Last year US10 million was derived from export. In a recently held cluster development workshop, lack of adopted varieties, micropropagation facilities capable of providing cheap planting material and freight rates were generally agreed as the major limitations to expanding production 10-20 fold within the next 10 years. Overcoming these problems can reduce the cost of production, improve productivity and quality leading to greater profitability and reduced risks.

UWI-SA Research initiatives:

1. UWI has initiated anthurium breeding with Kairi Blooms Ltd. (the largest anthurium grower in T&T) towards developing tropically adapted anthuriums with resistance to bacterial blight and bacterial spot diseases with funding from CARTF (US 50,000.00). This will reduce the risk as well as management costs allowing smaller resource-poor farmers to adopt anthurium growing.
2. UWI with seed funding from IDB (US 50,000) has initiated a bioengineering project to develop novel colours in anthurium. This will allow greater market penetration and premium price for anthurium. This project has also led to micropropagation protocols, which work well with many anthurium varieties.
3. UWI has developed screening methodologies to identify resistance to anthurium resistance with funding from the Deans grant (TT 100,000).
4. UWI has initiated a semi-commercial micropropagation of anthuriums to meet the demands of the local growers.

Outreach

UWI-SA is seeking a private sector partner to establish a tissue culture facility to propagate genetic materials coming out of the breeding and bioengineering work. This will allow the anthurium industry to develop in T&T and in the region. Anthurium growing is suited to the small holding size of island-states and should be one of the new thrusts in the diversification efforts. UWI can derive benefits based on royalties as well as through micropropagation.

CASE-2: REDUCING THE REGIONAL IMPACT OF GEMINIVIRUSES ON TOMATO AND PEPPER

Tomato and pepper are important crops in the region, with the latter becoming a major export crop. The varieties grown in the region are extremely susceptible to geminiviruses, which reduce the yield by as much as 40% and therefore reduce the competitiveness of the region.

UWI-SA Research initiatives

1. UWI-SA is involved in an EU funded regional project (1M US) in developing biotech tools to diagnose geminiviruses and to develop control strategies to minimise losses by IPM and resistant varieties. The countries involved are Cuba, DR, Guadeloupe, Martinique, Trinidad and Tobago and UK .
2. UWI-SA has established a DNA fingerprinted germplasm collection of pepper varieties, which is now being used to identify resistance to viruses funded through a Dean's grant, using ELISA and DNA hybridisation assays.
3. UWI-SA is participating in a CARDI-led project on developing purified varieties for the export trade in peppers. (Funded by CARTF, IICA and the Agricultural Society of Trindad and Tobago).

Outreach

The pepper germplasm collection will form a reference collection and if databased could form the basis of testing varieties under the UPOV convention. Further, through its collaboration with CARDI the benefits can be extended to the entire region.

CASE-3: SUSTAINABLE MANAGEMENT OF FOREST GENETIC RESOURCES

Forest genetic resources are especially vulnerable in small island states and can be easily lost if not properly managed. Forests have been exploited using different management regimes for over a century in T&T. However, the efficiencies of these management systems have not been determined nor has the minimum size of national parks to conserve the genetic variability determined. These are important questions that need to be answered so that small island states can sustainably manage forests. Biotechnology provides important tools to answer these questions.

UWI-SA Research initiatives

1. UWI-SA has initiated a project with funding from a Dean's grant to determine the genetic variability of national parks and the sustainability of forest exploitation strategies, using molecular markers. The project has developed biotechnology tools to assess the variability of 5 forest species.
2. UWI-SA has applied for funding from CDB (US 37,000) to continue the work into the other Caribbean islands.

Outreach

Based on the project a manual will be developed outlining the threats and methods of managing the forest genetic resources in a sustainable manner. This can be extended to other countries in the region.

CASE-4: MANAGEMENT AND UTILISATION OF CACAO GENETIC RESOURCES

UWI-SA houses one of the largest international cacao germplasm collections, and is one of two collections of cacao recognised by the International Plant Genetic Resources Institute. The Cocoa Research Unit (CRU) is an important international research organisation. Work of CRU drives national research programmes in many developing countries, which grow cacao, and remains the only international effort in Trinidad and Tobago. Biotechnology tools are used in the management of the collection and utilisation of the collection.

UWI-SA Research initiatives

1. Cacao genome mapping to identify QTL's and molecular markers for important agronomic traits such as blackpod and witches' broom disease resistance, flavour traits etc. This will accelerate the breeding of these traits into good genetic backgrounds.
2. A DNA fingerprinting project is being undertaken to uniquely characterise each accession, with funding from USDA and Cadbury's.
3. Tissue culture and cryopreservation of cacao. Research has begun in the areas to develop cheaper methods of conservation of cacao genetic resources.
4. Molecular genetic diversity of the cacao genetic resources will inform researchers as to the deficiency of the collection so that targeted collections can be made to enhance the genebank collection.

Outreach

CRU should become a UPOV approved testing facility to provide intellectual property services to the entire world. CRU could also assist the protection and marketing of varieties bred by the T&T national research programme.

Table 8 Biotechnology-related organizations in the Caribbean

- University of the West Indies http://www.uwicentre.edu.jm/
- IICA, the International Institute for Co-operation in Agriculture http://www.iica.int/home.asp
- INFOTEC http://www.infotec.ws/ - FORAGRO-IICA's Science and Technologica Information System for the Agriculture Sector of the Americas – includes weekly information on bitechnology and has an specific section on it and related isuses. It is for LAC and of course it covers the Caribbean.
- The Caribbean Agricultural Research and Development Institution, CARDI www.cardi.org,
- PROCICARIBE, the Caribbean Agricultural S&T Networking System http://www.procicaribe.org/
- The Caribbean Biotechnology Network Project http://www.cafpro.org/cbnp.htm
- The Multinational Biotechnology Information System (SIMBIOSIS http://www.bdt.org.br/bdt/simbiosis,
- REDBIO Technical Co-operation Network on Plant Biotechnology in Latin America and the Caribbean : REDBIO/FAO
- The United Nations University BIOLAC or Biotechnology for Latin America and the Caribbean http://www.biolac.unu.edu/English/homenglish.htm
- Pan American Marine Biotechnology Association http://www.pamba.org/index.html
- Regional Biotechnology on-line publication maintained by REDBIO, http://www.ejbiotechnology.info/ Newsletter
- SPORE published by the Technical Centre for Agricultural and Rural Cooperation (CTA) www.cta.nl
- Other regional journals with agricultural biotechnology articles include the Proceedings of the Annual Conferences of the Scientific Research Council http://www.src-jamaica.org/, Jamaica
- National Agricultural Research Institute, Guyana http://www.agrinetguyana.org.gy/nari/
- CARIFORUM Agribusiness Research & Training Fund, Research & Training Providers http://www.cafpro.org/CARTF/retrain/default.html

Table 9 CARICOMP: A Caribbean Network of Marine Laboratories, Parks, and Reserves for Coastal monitoring and Scientific Collaboration – an example of a successful Caribbean Network

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CARICOMP = Caribbean Coastal Marine Productivity program (CARICOMP) = a regional scientific program and a network of marine laboratories

Date of inception: 1990
History: The CARICOMP network grew out of the 35-year old Association of Marine Laboratories of the Caribbean (AMLC).

CARICOMP Steering Committee:

- Marine Science Program, Department of Geological Sciences and Belle W. Baruch Institute for Marine Biology and Coastal Research, University of South Carolina, Columbia, USA
- Florida Institute of Oceanography, Florida, USA
- Instituto de Investigaciones Marinas y Costeras, Columbia
- Instituto de Ciencias del Mar y Liminologia, Unversidad Nacional Autonoma de Mexico, Mexico
- Bonaire Marine Park, Netherland Antilles
- Instituto de Technologia y Ciencias Marinas and Departmento de Estudios Ambientales, Universidad Simon Bolivar, Venezuela
- Department of Microbiology, University of Georgia, USA
- Centre for Marine Sciences, University of he West Indies, Mona Campus, Jamaica
- Department of Environmental Sciences, University of Virginia, USA

The CARICOMP Site Directors and the Steering Committee meet annually at a participating site to report on network progress and problems, to discuss funding and logistics, to refine data collection and analysis, and to report on measurement protocols.

Number of participating laboratories: Negotiated MOU with 27 institutions in 17 counties over a ten-year period. The MoUs specify the responsibilities of each institution to the network, including the nomination of a Site Director and the obligations of the network in terms of equipment and logistical support.

Co-ordination: Data Management Centre (established by this network) at UWI, Jamaica – provides centralized data processing and data storage – sends analysis to each lab quarterly. Also, the Data Management Centre coordinates regional investigations of transient oceanographic, biological, and meteorological phenomena and serves as a clearinghouse for new ideas and methods.

Main focus: Study of land-sea interaction processes in the Wider Caribbean region by the use of identical methods at diverse sites across the wider Caribbean.

Protocol: Countries make standardized synoptic ecosystem measurements in relatively undisturbed mangrove, sea grass and coral reef systems, and relevant oceanographic and meteorological measurements.

Results:
CARICOMP Methods Manual–Level I drafted; consisting of a number of standardized observations and simple measurements to be taken by each participating instituiton.
Equipment sent to each participating institution.
Detailed site characteristics now available for 21 of the 27 participating institutions.
Capacity to respond to events related to coral bleaching, mass mortality, disease, and storms.
Workshops and training sessions.
Published scientific papers.
