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ISSUES IN BIOTECHNOLOGY TEACHING

Biotechnology in Mauritius: current status and constraints

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Agriculture today faces the challenge of sustainable productivity and improved food security on a shrinking area of land under cultivation. Until recently, biotechnology has been viewed as an expensive technology affordable only by rich industrial countries. However, it is now increasingly considered as an essential tool for developing countries to tackle the numerous problems of underdevelopment. Unfortunately, to date, Mauritius, like many other countries in Africa, lags far behind in development, use and commercialisation of biotechnology. This paper outlines the current status of biotechnology in Mauritius, some important constraints faced, as well as how policy makers are planning to make Mauritius "assume the role of a service provider and know-how disseminator in the field of biotechnology by acting as a regional hub and a regional nursery".

Mauritius is a small country (2040 Km^2) (Figure 1) with a population of 1.2 million.

The agricultural and manufacturing industries are significant in Mauritius, but tourism and textiles make up the bulk of the country's income. Other industries include: food processing, chemicals, metal products, transport equipment and non-electrical machinery. The highlights of the economy of Mauritius are shown in Table 1.

The agriculture sector is dominated by sugar cultivation, which occupies most of the arable land. However, regarding the sugar industry, there has been a constant decline over the years in: (Dinan, 2003).

- the area under cultivation from 85,895 ha in 1968 to 76,478 in 2003;
- its contribution to GDP from 27.6% in 1968 to about 4.5% in 2003;
- the percentage of total exports from 96% in 1968 to about 19.6% in 2003;
- the percentage of employment from 45% in 1968 to about 6% in 2003.

The agricultural sector's contribution to the economy as a whole has declined over the years contributing to only about 8% of total GDP in 2003 (Dinan, 2003). The main reasons of these declines have been attributed to the rapid growth of the manufacturing industries, the constant growth of the tourist industry and the emergence of the financial services. With the development of a high tech facility on the island there is expected to be much emphasis on the ICT sector. Mauritius is emerging as a major business and financial sector in the region and in August 1995 became a member of the Southern African Development Community (SADC).

The government being fully aware about the stiff competition of our sugar on the EU market and the significant boost required to the other agricultural products in terms of growth rate and exports, has come up with two strategic plans; the Sugar Sector Strategic Plan (SSSP) 2001 – 2005 (MAFTNR, 2001) and the Non-Sugar Sector Strategic Plan (NSSSP) 2003 – 2005 (MAFTNR, 2003a). Modern biotechnology is one of the key emerging technologies which the Non-Sugar Sector Strategic Plan has given paramount importance in "catalysing the targeted technological reform" for the non–sugar sector. In fact, developing countries must harness successfully biotechnology to sustain economic growth and competitiveness. The ability to commercially exploit research in this area is also of prime importance. While developed countries have made important progress in biotechnology, with a strong leadership of USA in this sector, the lack of facilities and professional skills in biotechnology limits Research and Development initiatives in the developing and the least developed countries; and restricts their full participation in national and regional ventures in sustainable development (Da Silva et al. 2002). Unless substantial steps are taken now by the developing countries, the gap between developed and developing

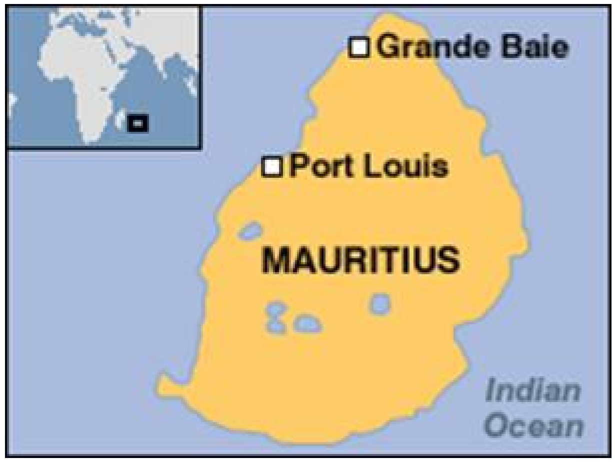

Figure 1. Location and map of Mauritius.

economies will only continue to widen in the short, medium and long term.

The importance of biotechnology in agriculture stems from the recognition that research at the cellular and molecular levels has proven its potential to solve fundamental problems in food production whereas conventional techniques have been of limited success. Biotechnological tools and methods can address a wide range of problems in agriculture, from the early diagnostic of diseases for efficient crop protection to the rapid production of superior high yielding disease resistant crop varieties. Hence, not surprising, many countries have now integrated biotechnology in the planning of their agricultural programmes. In 2003, almost one-third (30%) of the global transgenic crop area of 67.7 million hectares, equivalent to over 20 million hectares, was grown in developing countries (James, 2003). Moreover, knowledge-based industries are becoming major components of the leading world economies. Government and investment funds look to investment in new and emerging technologies since the growth rate can be quite substantial and there is also a high rate of job creation. Biotechnology is in fact one of the main challenges and forms part of the agenda of the Government of Mauritius.

BIOTECHNOLOGY APPLICATION AREAS IN MAURITIUS

Micropropagation

Mauritius has been using traditional biotechnology such as the production of beer, alcohol and vinegar for many years. However, biotechnology was introduced in our agriculture in 1985 with the setting up of the first tissue culture laboratory at the MSIRI for the multiplication of potato and eventually of sugarcane and it became fully equipped in 1993 (Ramkissoon, 2002). A new biofactory was built in 1997 mainly for the large-scale multiplication of sugar cane. MSIRI handles the whole range of techniques associated with micropropagation, from meristem culture to pathogen indexing. It also carries out the diagnosis and the indexing of plant diseases for FARC and MAFTNR upon request. In the year 2002 alone, the MSIRI produced more than 85.000 plantlets of a number of promising sugar cane varieties such as the M 1394/86, M 1400/86, M 1186/86, M 2256/88 and M 2024/88 (MSIRI, 2002). In the public sector, biotechnology was introduced in our agriculture in 1986 with the setting up of the tissue culture laboratory at Barkly Experimental Station of the Ministry of Agriculture, Food Technology and Natural Resources (MAFTNR). Plant tissue culture was introduced as part of our Agricultural policy to increase crop diversity and crop productivity in order to achieve our aim of increased local food production and reduced dependency on imported foods. During the International Workshop on Management Strategies and Policies for Agricultural Research in Small Countries held in Mauritius in 1992, plant tissue culture was identified as one of the priorities for the short-term solutions of our problems (Antoine and Persley, 1992). Plant tissue culture is of particular interest to Mauritius because it is not very demanding at the technological level and it also belongs to the category of comparatively low-cost technology compatible with our economic status.

Six plant tissue culture laboratories are at presently operating in Mauritius: two at the University of Mauritius, for teaching and research purposes and the four others for large scale production. These are: the Food and Agricultural Research Council (FARC) tissue culture laboratory, the Barkly laboratory of the MAFTNR, the biofactory of the Department of Biotechnology at the Mauritius Sugar Industry Research Institute (MSIRI), and Micro Lab Ltd. a private commercial laboratory.

The FARC laboratory houses the most spacious and

Table 1. Highlights of the economy of Mauritius.

	Agriculture		Manufacturing		Tourism	Financial Services
	Sugar	Other	Export Processing Zone (EPZ)	Other		
Turnover Rs. Billion	9.0	4.0	33.5	30.0	18.0	30.0
Contribution to GDP - %	4.5	3.5	11.0	10.6	6.0	15.0
Numbers employed	22000	26000	82000	52000	40000	20000

Source: Dinan, 2003.

modern up-to-date tissue culture facilities in Mauritius with an attached first class controlled-environment conditioning plant. The latter was set up in 1990 to harden *in vitro*-grown plantlets imported from foreign laboratories to accelerate crop diversification. The tissue culture laboratory was set up at a later stage in 1995 to produce *in vitro* plantlets locally. FARC takes care of the introduction of new and elite crop varieties to Mauritius. Its tissue culture production targets mostly project-oriented, medium and large-scale planters. Up to now, tissue culture has been carried out mainly through the bulking-up of imported starter cultures using commercial protocols. The Barkly tissue culture laboratory production aims at the range of plant species not covered by FARC and caters mainly the needs of the small-scale planters as well as those of the general public. The experimentations and adaptations of micro propagation protocols at Barkly over the years include anther culture of tobacco, tissue culture of vanilla, propagation of local selections of anthurium, strawberry, pineapple, asparagus and orchids (Ramkissoon, 2002). However, none of these have been produced on a large scale as Barkly tissue culture laboratory still lacks a hardening unit and increased nursery facilities are required for full-scale operation of the laboratory. Micro Lab Ltd. was created in 1987 by Anthurium Export Ltd. with the aim of servicing the needs of its member Anthurium growers. However, it also produces a wide range of other ornamental plants and so far, has produced over three million plants.

The total annual production capacity for Mauritius, including all four large-scale production laboratories, is around one million plants with expertise mainly in Anthurium, sugarcane, bananas and other ornamentals. Anthurium and sugar cane are the only two crops micro propagated on a truly large scale so far. The production of other plant varieties has remained limited because of lack of demand from growers.

Crop breeding

The application of biotechnology to crop breeding has provided breeders with additional tools to increase the efficiency of selection processes so as to reduce the time required to produce new plant varieties. The use of molecular techniques has increased the range of selection criteria, which are no longer dependent on environmental factors and phenotypic expression. Hence, screening can take place early in the selection process, reducing the costs of breeding new varieties.

So far, molecular techniques have been used only in sugar cane breeding at the MSIRI. The major objectives have been to identify molecular markers linked to resistance to the diseases, rust (*Puccinia melanocephala*) and yellow spot (*Mycovellosiella koepkei*) and to the leaf scald disease caused by the bacterium *Xanthomonas albilineans*. Sugar cane populations from various crosses are investigated by restriction fragment length polymorphisms (RFLP), random amplified polymorphic DNA (RAPD) and amplified fragment length polymorphisms (AFLP). Collaboration with the Centre de Coopération International en Recherche Agronomique pour le Développement (CIRAD) in Montpellier, France, has enabled the progress of research projects on genetic diversity of sugar cane varieties and the resistance of the plant to leaf scald disease. In 1995, MSIRI purchased a “Biorad” Biolistic gun and in 1996, work was initiated on the genetic transformation of sugar cane to produce herbicide (Basta)-resistant varieties (MSIRI, 1996). Objectives over the next decade include genome mapping, marker-assisted selection and genetic transformation for other selected agronomic traits.

MSIRI joined the International Consortium for Sugar Cane Biotechnology (ICSB) set up by cane sugar producing countries in 1992 to derive maximal benefit from biotechnology without excessive financial input. In return for financial contributions to ICSB, Mauritius benefits from research information, experimental data and new technology.

Diagnosis of diseases

The diagnosis of plant diseases and the identification of their causal agents is a prerequisite for the control of crop diseases, which can cause serious economic losses. Previously, the identification of pathogens has relied on biological indexing. However, this technique precludes detection prior to symptom expression. Hence, other diagnostic techniques such as, microscopy, isolation and serology have been widely used. Newly developed molecular techniques have a higher sensitivity, specificity and accuracy thereby increasing the efficiency and reliability of pathogen detection. They are usually based either on serological tests using monoclonal and recombinant antibodies or on nucleic acid sequence-based techniques. The latter techniques are based either on the amplification of DNA by polymerase chain reaction (PCR) or restriction and hybridization analysis to give restriction fragment length polymorphisms (RFLPs). In addition to the rapid and accurate identification of the pathogens, they can also provide information on the pathogen genomes and the nature of their interaction with the host plants. The major advantage of molecular techniques arises from the early detection of diseases which allows a more efficient control of disease spread.

Monoclonal antibodies with the potential to differentiate among races of the gumming disease pathogen of sugar cane and African serovars of the leaf scald bacterium *Xanthomonas albilineans* were once being produced at the MSIRI for disease diagnosis (MSIRI, 1998). Although the MSIRI has stopped its production of monoclonal antibodies, it still uses this technology in disease diagnosis. The pathology division of the MAFTNR and that of Agricultural Research and Extension Unit (AREU) of FARC are hoping to use monoclonal antibodies in the early detection of a number of diseases such as anthurium blight, citrus greening organism, tomato mosaic virus, cucumber mosaic virus and zucchini yellow mosaic virus. Until recently the use of nucleic-acid based techniques was limited to the MSIRI which uses PCR and many of its derived techniques, reverse transcription-PCR (RT-PCR), RAPD, RFLPs and AFLPs on disease of sugar cane and the interline crop, potato. AREU has recently started using some of these techniques on disease of other crops. The Plant Pathology Division of the MAFTNR has recently acquired a number of equipment under the FAO Project TCP/MAR/0165 – Strengthening Plant Health Management Capability in Seed and Plant Certification Schemes - and has trained a number of its personnel in the use of molecular techniques for disease diagnosis.

Animal production and animal health

In Mauritius, the manipulation of animal reproductive biology has been targeted mainly at livestock in view of its major economic importance. Among the methods used are, the artificial insemination of cows using semen from superior breeds, the use of *in vitro* fertilisation (IVF) techniques and the induction of super ovulation by hormones for the production of multiple embryos in cows and their recovery for later implantation in surrogate mother cows. The high rate of success in embryo transfer has increased the reproductive capacity of cows from an average of 4 calves a lifetime to more than 25, enabling the increased utilisation of outstanding genetic potential in breeding programs and a rapid expansion of rare genetic stocks. The minimal costs of embryo transport compared to live animals allow for an easier and wider dissemination of elite stock. Calves of imported genotypes born to local breeds are generally better adapted to their new environment. Other applications include the sexing of semen and embryos and the use of recombinant hormones to increase milk productivity and the quality of meat. Animal nutrition can be improved through the use of feed, modified by fermentation to increase digestibility or through the use of improved strains of rumen microorganisms.

A major application of biotechnology in Mauritius in livestock improvement would be the use of molecular markers both in conventional and transgenic breeding strategies. In conventional breeding for example, molecular markers could be used in parentage determination, genetic distance estimation, determination of twin zygosity, sexing of pre-implantation embryos, identification of disease carrier, gene mapping and marker-assisted selection. In transgenic breeding, molecular markers can be used as reference points for identification, isolation and manipulation of the relevant genes, and for identification of animals carrying the transgenes. The use of molecular markers in the selection of breeding traits, genetic mapping and rDNA technology makes available a wider range of tools for genetic improvement of livestock species. Applications of biotechnology in animal health on the other hand are concerned mainly with the prevention of animal diseases and their control through the use of diagnostic tools and the production of more efficient and cheaper vaccines. The use of molecular diagnostic tools, serological or DNA-based, for the early detection of pathogens, enables a better control of the spread of diseases. The large-scale production of cheap recombinant vaccines has enabled more efficient animal protection. The fact that some 27% of total biotechnology expenditures of the Consultative Group on International Agricultural Research (CGIAR) is devoted to animal health indicates the importance of this sector.

The veterinary services of the MAFTNR take care of animal production and animal health in Mauritius. They are operated by five veterinarians working in a single laboratory. The main targets are to improve our local meat and milk production to meet a higher proportion of our local consumption and to reduce the costs of these two items on our imported food bill. At present, the annual consumption of milk in Mauritius is 135,000 tons with the milk market fast expanding because of the increased consumption of dairy products. Local producers can meet only 5% of the demand at a highly subsidised price costing the government some Rs 30 million a year. The remaining 95% is imported as dried milk powder for over Rs 700 million a year (MAFTNR, 2003c). Livestock improvement through artificial insemination using imported high quality semen aims at obtaining 4,500 lt per lactation instead of 3,000 lt. However, the insemination technique used has been observed to produce a low rate of success and its efficiency needs to be improved.

Diagnosis of diseases is still being carried out using conventional methods. The MAFTNR recognises that the Veterinary Division requires to be modernised and start using modern diagnostic tools that are faster and more effective in the diagnostic of diseases such as Newcastle disease and swine fever. A small volume of vaccines (against Newcastle disease and Fowl pox) is produced using imported seed vaccines. However, the local vaccines are produced at higher cost and of lower quality than commercial vaccines.

Although formal links exist between the Mauritian veterinary services and British Universities and specialised animal improvement centres in South Africa and France, these links have functioned more for the exchange of information and advice rather than for research collaboration. At present, a single research project, funded by the International Atomic Energy Agency (IAEA), is being carried out on the improvement of reproductive performance in livestock using radio-immune assay (RIA) techniques.

Treatment / use of agricultural wastes

Waste treatment has become one of the most important areas of application of biotechnology today in view of the ever-increasing pollution from a growing world population dependent on an ever larger number of industries. The biotechnological treatment of wastes relies on the utilisation of the vast diversity of microorganisms and their versatile catabolic processes to degrade or transform wastes either into useful biomass or into compounds less damaging to the environment. Apart from its positive effect on public health and environmental hygiene, the application of biotechnology can also contribute towards the production of energy. With the increasing awareness of the general public and mounting international pressure for environmental protection, the biotechnological treatment of wastes have become globally the methods of choice for the control of pollution since traditional strategies, based on dilution, burial or incineration, have already proven their ineffectiveness. However, most recent technologies in this field have been developed by private enterprises in industrial countries and are not easily accessible to developing countries.

Very few cases of biotechnological treatment of agricultural wastes are known in Mauritius. Two pilot projects are being run, one at the St Martin pig farm and the other at Union Sugar Estate with the objective of integrating the control of pollution into the farming system (Chan 1997; Chan, 1998). The treatment involves the preliminary anaerobic fermentation of organic wastes in a digester, which produces biogas while reducing the biological oxygen demand (BOD). The degradation of wastes continues through an aerobic process in shallow basins populated by natural algae. After transfer to a deep fish pond, the wastes are further oxidized until they are completely broken down into nutrients ready for recycling and a water suitable for irrigation. This farming system, on top of being environmentally friendly, provides for an economically-viable system with minimal input and the production of biogas, fertilizers and high protein feeds as renewable resources. A few projects on waste treatment are still at the research level at the University of Mauritius. The utilisation of bagasse and scum, important by-products of the sugarcane industry, for the purpose of composting is being investigated at the Faculty of Engineering. After successful bench scale trials on a model aerobic system, pilot scale trials (60 tons) have been set up at Rose Belle Sugar Estate to produce high quality compost for sugarcane fields in minimal time. Trials on large scale using aerated static pile system are expected to start in the near future. The composting technique may be applicable to municipal wastes, sewage sludge and other organic wastes. Research on the processing of waste effluents from sugarcane and textile factories is also being carried out to reduce their biological oxygen demand (BOD) and to recycle active biological compounds. Two approaches are used in the recycling processes: the upflow anaerobic sludge blanket (UASB) high rate anaerobic process and phyto-remediation using water hyacinths. Although both projects are still at an early phase, a 50 m^3 UASB treatment plant has been constructed in 1997 for experimentation at the Rose Belle sugar factory.

Production of useful substances by plants and microorganisms

The use of microbes and plant cell cultures have an increasing role in the agro-industrial sector today in the production of food and other useful substances. The utilization of microorganisms or plant cells as bioreactors for producing proteins and other metabolites in bulk quantities at low cost provides enormous scope for the industrial transformation of primary agricultural products into food and other fine chemicals, which were previously of limited availability. The production of enzymes, additives, flavourings, colourings and other components have transformed the food processing industries just as the large scale production of secondary metabolites such as antibiotics and antitumour drugs have transformed the pharmaceutical industries. The production of transgenic microorganisms and plants, targeted for specific job functions, widens the scope for the industrial production of high value compounds in agriculture. Plants have been transformed, which are now capable of producing complex proteins like antibodies or vaccines, opening up a new era of molecular farming.

The main applications in Mauritius are in the processing of dairy products, the brewing industries and in the transformation of sugarcane by-products. Most of the fermentation processes used locally form part of traditional food processing and do not have any significant input from new biotechnology. The average annual production of molasses in Mauritius over the past decade is about 155,000 tons (Central Statistical Office, 2002). According to Dinan (2003) and the Mauritius Chamber of Agriculture (2002), almost 75% of the molasses is exported. For the year 2000-01, for example, out of the 144,027 tons produced, 25,016 tons were exported to South Korea, 78,646 tons to the USA, and 17,719 tons to the UK (Mauritius Chamber of Agriculture, 2002). Latest figures available for the year 2002 indicate a similar trend (Mauritius Chamber of Agriculture, 2002). Therefore, only about 25% of our annual production of molasses has been used locally in the production of alcohol and animal feed. This figure, however, is most likely to increase with the increase in the production capacity of a new alcohol production plant. Although the biotechnology conversion of molasses into high value compounds has huge potential and has been used elsewhere, such as in Brazil, for the industrial production of ethanol, citric acid, lactic acid and acetic acid and amino acids for chemical industries and of single cell protein for food and animal feed industries, there has not been any development in this area in Mauritius. The high cost of setting-up production plants, the uncertain commercial viability of the operations as well as the uncertain existence of a market for the end products are strong deterrent factors for Mauritian industries. An unsuccessful attempt at producing yeast had previously been made at Deep River Beau Champ sugar estate. Hence, the bulk of our molasses is presently exported for lack of utilisation locally. Investigations on the possible production of proteolytic enzymes, commonly used in agro-industries, from pineapple wastes and of polyphenols and alkaloids, well-known antibacterial agents and vascular protectors in the pharmaceutical industry, from selected local plants, are being carried out at the University of Mauritius.

CONSTRAINTS

So far, biotechnology has not yet produced the expected impact on the economy of Mauritius. A number of constraints, financial and administrative, have been identified as casual agents delaying progress. Many of these problems can only be addressed at a high and central level, beyond the institutional level. Until these constraints have been sorted out, biotechnology cannot play its role and the high expectations from this technology are not likely to materialise.

Inadequacy of funding

In countries where biotechnology has taken off, it is observed that high government investment has been at the base of the building of national and international enterprises. One of fundamental reasons for the early emergence of biotechnology in USA and in Singapore has been the strong background of national research and development and the creation of a special budget to promote the growth of commercial biotechnology. Public biotechnology companies in USA spend on average US $ 5.2 billion per year (Hodgson and Lähteenmäki, 1997) with US $ 2.2 billion on agricultural biotechnology alone (Keya, 1997). Investment in biotechnology in the developing world is at a much lower level. Except for countries like Brazil, which has an advanced biotechnology programme and is estimated to have spent US $ 100 million in 1997. In 1996, South Korea, invested US $ 154 million. In 1997, South Korea increased its financial support by another 28% (Saesuga, 1998), in spite of a drastic overall cut of US $ 7 billion in their total budget because of economic crisis. The Korean Biotech 2000 action plan benefits from the support of seven ministries, Science and Technology, Agriculture, Forestry and Fishery, Health and Welfare, Trade, Industry and Energy.

In Mauritius, at present, there are six agricultural biotechnology laboratories financed by public funds: four for tissue culture and two for molecular biology. Research and Development performed by the private sector in Mauritius is limited (Beintema et al. 2003). Future perspectives for the development of our laboratories reveal a need for an increase in the number of molecular biology facilities for plant breeding and/or phytopathological diagnosis. Apart the MSIRI laboratories, which benefit from satisfactory funding, inadequate funding appears to be the single most important factor holding back the development of the other laboratories. In general, there seems to have been an overall underestimation or lack of appreciation of the level of funding required for biotechnology programmes to get off the ground and of the sustained funding required subsequently for operation. Because of the high cost involved, there is a special need for long term planning in resource allocation for the optimal utilisation of any infrastructure set up. The drying-up of funds at intermediate stages or limited operating budgets have been a cause for low achievements and have reduced benefits to a fraction of that expected. Four separate steps need to be recognized in the funding process to enable the full-scale functioning of the facilities set up.

i. Funding to set up the physical space of the laboratory, which needs to be large enough to house the voluminous instrumentation associated with this equipment-intensive technology.

ii. Funding to purchase the critical mass of equipment required for molecular work.

iii. Funding to meet the operating costs of expensive reagents, renewable supplies and technical assistance.

iv. Funding to finance specific research projects over the period of time required to generate results.

With proper financial planning providing for sustained funding, our laboratories can become more productive.

Unavailability of qualified staff

The unavailability of suitably qualified scientific, technical and supporting staff considerably handicaps the application of biotechnology in Mauritius. Most of the staff in service do not have the necessary scientific background to use the new technologies. Hence, in-service staff training is urgently required to enable the use of the new technologies. The Faculty of Agriculture at the University of Mauritius has established a teaching and research programme in modern agricultural biotechnology. In parallel with the scientific infrastructure, there is a need to build up an infrastructure of supporting services for equipment repair and maintenance. The present lack of trained engineers for servicing sophisticated equipment compels frequent recourse to the manufacturing firms abroad for repair. The challenge after training our workforce will be in manpower resource management to avoid losses of our skilled workforce.

Chronic understaffing of laboratories

This very serious issue prevents the efficient operation of the public funded laboratories and needs to be addressed urgently to enable these laboratories to function properly. This , however, does not seem to be a problem for the private owned biotechnology laboratories. The chronic inadequacy of technical and other supporting staff forcibly requires highly qualified staff to attend to responsibilities outside their scope and prevents them from focusing on their work. The deployment of staff in jobs other than those for which they were recruited represents a wasteful use of manpower resources.

Lack of infrastructures compatible with active progress in biotechnology

Apart from the MSIRI, which benefits from reasonably good infrastructures acquired from a long and well-established experience in research, none of the other institutions are supported by the range of modern infrastructures required to keep up-to-date in biotechnology. There is an urgent need to set up central facilities at Réduit that can be shared by all user institutions.

Among the facilities most urgently needed, are the following :

- Repositories of biotechnology resources such as microbial type culture collections, DNA clone libraries, germplasm centers and stock centers to maintain the collections and to supply authentic materials and cultures to research institutions and industries.
- A biotechnology information service to promote the exchange of information by all available means. It will be responsible for the acquisition and management of all databases, information resources and reference standards relevant to biotechnology, for linking-up Mauritius to biotechnology information services and on-line databases and for establishing easy systematised access to the data banks.
- Although facilities for obtaining research information and communications at the University of Mauritius, MSIRI and FARC libraries, the Documentation Centre of the MAFTNR and the Centre Syfed have been significantly improved in recent years, access to additional sources of information, such as the gene-bank information systems of other countries such as, the Australian National Genome Information Services (ANGIS), could be set up via bi-lateral agreements with friendly countries so as to widen the source and range of data banks.
- A biotechnology cooperation service in charge of linking up Mauritius to biotechnology research networks worldwide. This service will be an indispensable tool to maximise opportunities available internationally for training and to encourage rapid development.

Absence of a regional technical cooperation network

Comparison of the agricultural development in the African region with that of other regions with active biotechnology networks suggests that the absence of a regional network could have limited the development of biotechnology in our agriculture. So far, research collaborations are usually set up either by individual institutions with specialised laboratories abroad on specific projects or with crop-based networks. Until recently, the only wide area network, of which Mauritius forms part, is the Plant Biotechnology network of the Agence Francophone pour L'Enseignement Supérieur et la Recherche-Universités des Réseaux d'Expression Française (AUPELF-UREF), grouping all French-speaking universities and promoting North-South cooperation. There seems to be a pressing need for Mauritius to join as many wide area non crop-based research networks as possible, particularly those involving other developing countries with comparable economic status and similar crop research interests. Mauritius has recently joined the REDBIO network for plant biotechnology in the Latin American and Caribbean region, grouping some 409 laboratories from 27 countries, in order to benefit from technical assistance, training in advanced technology and sharing of resources with other member countries. However, for the sustained development of biotechnology in Mauritius, the setting-up of a regional network will be needed. The support of the FAO Global Plant Biotechnology Programme, whose aim is to strengthen institutions in developing countries in the field of plant biotechnology, would be of capital importance for the success of this network.

GOVERNMENT POLICY AND INCENTIVES FOR BIOTECHNOLOGY

The Ministry of Agriculture, Food Technology and Natural Resources (MAFTNR) is the apex government agency to coordinate and regulate agricultural biotechnology activities in the Mauritius. The government of Mauritius has taken numerous steps to embark on the biotechnology research in agriculture since the early 1990's. It has initiated a number of endeavours to promote biotechnology integration in agriculture. With the rapid evolution of our local and regional economic context over the past few years, the MAFTNR has recognised biotechnology to be an essential, and increasingly important element of a critical strategy, integrating both conventional and biotechnological applications, in order to achieve future food security. This ministry has also recognised that “Biotechnology represents a promising futuristic tool to the Mauritian agriculture in responding to the numerous existing challenges within the sector and in addressing several of its most pressing weaknesses, at a pace that is unachievable, if at all possible, through conventional means” (MAFTNR, 2003a). In this context, the Ministry of Agriculture, Food Technology and Natural Resources is proposing the setting up of the Mauritius Agricultural Biotechnology Institute (MABI). A budget of Rs. 360 million has already been allocated to MABI. The latter is expected to solve most of the problems related to biotechnology in Mauritius as the main objectives would be “to provide adequate and readily accessible research facilities and support services for all institutions involved in non-sugar research in a most cost-effective manner through the efficient pooling of existing resources, equipment and human, and within a framework that would ensure their judicious utilisation; ….. centralisation of all activities pertaining to agricultural biotechnology research and application under one apex organisation endowed with the appropriate resources and amenities, would not only render these activities more time and cost-efficient by reducing the present inter-institutional dependency but will also ensure better efficiency in meeting established objectives within the sector” – (MAFTNR, 2003a). However, MABI is expected to be operational by 2008 (Beintema et al. 2003).

REGULATORY ISSUES

There are two main areas that are critically important to investment in biotechnology: Intellectual Property Rights (IPR), a key issue in transactions related to licenses, acquisitions, collaborations and strategic alliances to protect innovations and to maximize financial returns for its inventors (Doyle and Persley, 1996), and Regulatory Review to control the experimenting and release of GMOs and their products to avoid any potential harm to humans, animals and environment in accordance with the Cartagena Protocol on Biosafety. Several key international agreements and ongoing international discussions may impact the development and use of biotechnology. These agreements have broadened biotechnology beyond cooperative research and technical capacity building to now include trade and larger political, cultural and economic issues. The priority that many developing countries place on capacity building in policy and regulatory areas such as agricultural IPR and biosafety have increased. Developing countries face particular challenges in the implementation of the Protocol, not least because their capacity to implement, monitor and enforce national biosafety laws remains weak. In addition, they need to decide how to address a number of issues left to national discretion in the Protocol, and how to balance their rights and obligations under the Protocol with their commitments under the WTO. Developing countries also need to weigh the need to offer intellectual property protection against not doing so, at the risk of losing opportunities for technology transfer (Chetsanga, 2000).

In Mauritius, in accordance with the precautionary approach contained in Principle 15 of the Rio Declaration on Environment and Development, the Genetically Modified Organisms (GMO) Bill (MAFTNR, 2003b) was presented in the National Legislative Assembly on the 31st October 2003 by the Minister of Agriculture, Food Technology and Natural Resources and has now been adopted. The main objects of the Bill being (MAFTNR, 2003):

- to provide for measures to regulate the responsible planning, development, production, use, marketing and application of genetically modified organisms in the food and agricultural sector;
- to ensure that all activities, including importation, exportation, production, release and distribution, of genetically modified organisms and their derivatives be carried out in such a way as to limit possible harmful consequences to the environment

and risk to human and animal health; and
- to create a National Biosafety Committee whose objects and functions shall, *inter alia*, be to advise the Minister on all aspects concerning genetically modified organisms, publish guidelines and a code of practice and encourage public participation in decision-making processes.

Three other pieces of legislation, the Plant Protection Act (Revised), the Plant Varieties Act and the Seed Act are in the process of being finalised. In order to comply with International Conventions, the Government of Mauritius has also introduced in 2002 the following through the National Legislative Assembly: The Patents, Industrial Designs and Trademark Act; the Layout – Designs of Integrated Circuit Act; the Geographical Indications Act and; the protection Against Unfair Competition Practices Act. The Copyrights Act on the other hand dates back to 1997. It is expected that the policies being adopted would stimulate investment in biotechnology.

CONCLUDING REMARKS

The Government of Mauritius is in the process of setting up of the Mauritius Agricultural Biotechnology Institute (MABI). In the planning for Agricultural Biotechnology, we need to have our targets in agriculture clearly defined so that we can decide which strategy in biotechnology can best help us to achieve them. The constraints holding back progress have been identified; most of them can be resolved with the appropriate policies. Agricultural biotechnology needs to be addressed from a global point of view, from human resource development to applications. Manpower training will play a determinant role and emphasis should be put on producing high-level scientists rather than technicians. An assessment of the technologies acquired so far shows that plant tissue culture techniques for the purpose of micro propagation have been well established in Mauritius. Skills in molecular biology and rDNA technology, which will be essential for producing transgenics, are still limited to sugar cane research at the MSIRI and teaching at the University of Mauritius. With the need to extend these skills, significantly more difficult to acquire than tissue culture techniques, to the MAFTNR, the strategic planning will have to make ample provision for human resource development. It will also be of vital importance for Mauritius to join as many biotechnology research networks as possible as we cannot progress in isolation. These networks, in addition to providing our scientists with opportunities for training, collaboration in research and the acquisition of new technology at low cost, can become important technical forum to help us develop national and regional strategies.

As we move into the future, our investment in the right biotechnologies can help to contribute to our goals of achieving greater food sufficiency as well as of increasing our agricultural exports. With the abolition of subsidies to farmers and the opening of protected markets, the efficiency of our agricultural production will be crucial for us to remain competitive on the international level. The current non-reciprocal tariff preferences that Mauritius enjoys under the Cotonou Agreement will lapse by the end of 2007. Mauritius, being a net food-importing country, the effect of trade liberalisation will be a rise in our imported food bill, unless we can manage to increase food production locally. Superior transgenic varieties of sugar cane and other crops will have an important role to play here.

With sustained development in the African region and increased regional cooperation through the Indian Ocean Commission (IOC), the Indian Ocean Rim (IOR), the South African Development Community (SADC) and the Common Market for Eastern and Southern Africa (COMESA), there exists a regional consumer market of 300 million people and a potential export market of US$ 32,000 million. This opens the door wide for the development of agro-industries, which have previously been limited by the small size of the Mauritian consumer market. With the long tradition of agricultural production in Mauritius, the availability of land in Mozambique and the opening of custom barriers between countries of the region, ideal conditions seem to have been created for Mauritian entrepreneurs.

With increasing world interest in Africa, as the next market to conquer for industrial countries, especially after the American trade initiative in the Africa Growth and Opportunity Act (AGOA), Mauritius may now be in an excellent position to exploit its strategic geographical position on the doorstep of Africa. With our infrastructures in communication, information technology and scientific research relatively more advanced than that of many African countries, Mauritius could perhaps serve as a regional production base for biotechnology products for the African market in the future and "make Mauritius assume the role of a service provider and know-how disseminator in the field of biotechnology by acting as a regional hub and a regional nursery" **–** (MAFTNR, 2003a).

ABBREVIATIONS

AGOA: Africa Growth and Opportunity Act
ANGIS; Australian National Genome Information Services
AUPELF-UREF; Agence Francophone pour L'Enseignement Supérieur et la Recherche-Universités des Réseaux d'Expression Française
BOD; Biological Oxygen Demand
CGIAR; Consultative Group on International Agricultural Research
CIRAD; Centre de Coopération International en Recherche Agronomique pour le Développement

COMESA; Common Market for Eastern and Southern Africa
EPZ; Export Processing Zone
FAO; Food and Agricultural Organisation
FARC; Food and Agricultural Research Council
GDP; Gross Domestic Product
GMO; Genetically Modified Organism
ICSB; International Consortium for Sugar Cane Biotechnology
ICT; Information and Communication Technology
IOC; Indian Ocean Commission
IPR; Intellectual Property Rights
IVF; In Vitro Fertilisation
MAB; Mauritius Agricultural Biotechnology Institute
MAFTNR; Ministry of Agriculture, Food Technology & Natural Resources
MSIRI; Mauritius Sugar Industry Research Institute
NSSSP; Non Sugar Sector Strategic Plan
PCR; Polymerase Chain Reaction
RAPD; Random amplified polymorphic DNA
REDBIO; Red de Cooperacíon Técnica en Biotechnología Vegetal
RFLP; Restriction fragment length polymorphisms
RIA; Radio-Imuno Assay
Rs; Rupees (Mauritian)
RT-PCR; Reverse Transcriptase - PCR
SADC; South African Development Community
SSSP; Sugar Sector Strategic Plan
UASB; Upflow Anaerobic Sludge Blanket
WTO; World Trade Organisation

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