MAURITIUS RESEARCH COUNCIL

BIOTECHNOLOGY

September, 2001

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List of Abbreviations

DNA	*Deoxyribonucleic acid*
R & D	*Research and Development*
OECD	*Organisation for Economic Co-orporation and Development*
B. t	*Bacillus thuringiensis*
US	*United States*
IARCs	*International Agricultural Research Centres*
GV	*Granulosis virus*
MSIRI	*Mauritius Sugar Industry Research Institute*
GMO	*Genetically Modified Organisms*
SADC	*South African Developing Countries*
SWOT	*Strength, Weakness, Opportunities and Threats*
AS	*Agricultural Services*
AREU	*Agricultural Research and Extension Unit*
FARC	*Food and Agricultural Research Council*
MEDIA	*Mauritius Export Development and Investment Authority*
APEXHOM	*Association Professionelle des Producteurs Exportateur Horticole de Maurice*
UOM	*University of Mauritius*
APEPA	*Agricultural Products Export Promotion Authority*
IBD	*Infectious Bursal Disease*
NCD	*Non-Communicable Diseases*
DVS	*Division of Veterinary Service*
FT & NR	*Food Technology and Natural Resources*
MoH	*Ministry of Health*
MoA	*Ministry of Agriculture*
MRC	*Mauritius Research Council*
MSc	*Master in Science*
MPhil	*Master in Philosophy of Science*
PhD	*Doctor in Philosophy*
HPLC	*High Performance Liquid Chromatography*
CO_2	*Carbon Dioxide*
NPK	
AAS	
ITEC	
UNDP	*United Nation Development Programme*
GEF	*Global Environmental Forum*
SGP	
MSW	
HDPE	
HELP	
TS	
VS	
COD	
PvY	*Potato Virus Y*
PLRV	*Potato Leaf Roll Virus*

Executive Summary

The Potential benefits of biotechnology hold as much promises for developing as for developed countries, especially where the low input farming of developing countries is considered. Biotechnology is concerned to be of strategic importance, the policies and strategies should be country specific designed as a function of the particular condition prevailing within a country: creating new forms of wealth, new employment opportunities, social stability and alleviating poverty of subsistence farmers living perpetually under economic threat.

1. Introduction

Karl Ereky, a Hungarian engineer introduced the term ‘biotechnology’ in 1919, as the process that permits production of finished goods from raw materials using living organisms. Biotechnology can be coined scientifically as a technology that has permitted the development of new characteristics to living organisms or enhance a product that has been derived from an indigenous plant, animal or microbial cell. When a broader definition is connotated to biotechnology however, it cross-cuts areas such as waste recycling, environmental quality, pharmacology, cell fermentation, biomedicine, food and fuel production, farming and forensic.

In 1943 the first direct evidence that DNA carried genetic information appeared. “Modern” biotechnology began. Since the discovery of the structure of DNA (deoxyribonucleic acid) in 1953 by Watson and Crick, a new discipline called Molecular Biology has been drawing the interest of thousands of scientists all over the world. Today, the genetic code has been deciphered. Specific genes have been identified and located in living cells; with the result that scientists have developed techniques to manipulate them and thereby transferring them from one organism to another.

With the discovery by the Swiss microbiologist Werner Arber in the 1960’s of special enzymes, called restriction enzymes, in bacteria, it became possible to use this category of enzymes to cut the DNA double helical structure strands present within the protoplasm of an organism at precise points. This marked the beginning of recombinant DNA technology, today known as genetic engineering. In 1977 genes from other organisms were transferred to bacteria. This discovery led to the first transfer of a human gene to *Escherichia coli* bacterium. By the end of the 19th century biotechnology started flourishing.

Biotechnology therefore when regarded as the manipulation and transfer of genes can be looked upon as a new exact science. When the modified plant, animal or microbial cell is produced on a large scale in the external environment for the benefit of mankind through bio-industrial process, it suddenly acquires patented or intellectual property rights for commercial applications. Molecular biology together with microbiological applications is leading to development of vaccines, drugs, improved fermentation and solid waste treatment. Plant meristematic cell development is leading to rapid propagation of improved clonal varieties, better drought or disease resistant crops, and in the conservation of biological diversity. Consequently in developed and newly industrialised countries, a large number of commercial applications have been developed particularly in the pharmaceutical industry, forensics, in improving agricultural productivity and veterinary services, in cell fermentation technology, fuel production, and environment friendly technologies.

Moving from research in molecular biology to biotechnology leads to bio-industrial development. Biotechnology has application in the mining industry. The bacterium *Thiobacillus ferrooxidants* can use the molecules of copper present in chalcopyrite to form copper sulfate, which, in turn, can be converted chemically to obtain pure copper. This microbial mining process accounts for about ten per cent of copper production in the United States.

Based on background knowledge of structure and function of living systems, biotechnology has opened up new vistas for rapid agricultural, industrial and socio-economic progress. Biotechnology is highly science based, knowledge intensive, and an interdisciplinary field in which spectacular advances are taking place all over the world.

2. Objectives and Scope

Biotechnology primarily concerns the three principal domains where it has been applied: human health, agriculture and food, and bioremediation and other environmental applications.

The primary objective of biotechnology is the development of products, processes and technologies whose large-scale application would result in social benefits. However, major thrust may be given to start with, on manpower development, and, creation and strengthening of infrastructural facilities and legal recognition for innovation.

To build up a strong research and development base and manufacturing capabilities, it is imperative to develop infrastructural facilities viz-oligonucleotide synthesis, germplasm banks for plant and microbes, genetic engineering, R&D units, facilities for protein and peptide sequencing, centre for reproductive and molecular endocrinology, restriction enzymes and antibiotics development corsortium, trial and testing facilities of genetic manipulations in plant and animal sector, development of tissue culture and recombinant vaccine technologies, and development of diagnostic probes for highly specific diagnosis.

Major thrust should be equally placed to build biological resource centres, such as culture collections, databanks and bioinformatics

The objective of present biotechnology research in agriculture in Mauritius should be to refine the kinds of policies and strategies that would enable biotechnology to contribute to more efficient approaches to crop protection and production, for example drought and pest resistant cash crop and food crop varieties adapted to the local agro-climatic eco system. This should encapsulate with a process of product patenting, bio-safety ethics, product commercialization and intelligent marketing targeting to a new class of modern agricultural farmers producing to meet both local and export markets. The scope of R & D through biotechnology methods is also and answer to meet the challenge of alternate use for the 7,000 acres of land released from sugar cane cultivation.

3. Importance of Biotechnology in Mauritius

The power of biotechnology as a tool for industry is increasing rapidly. Novel enzymes, or biocatalysts, genetically engineered organisms and extremophiles have the potential to make industry cleaner and more efficient. In addition, biotechnology has also led to the creation of a wide range of materials such as biodegradable plastics, biopolymers and biopesticides, novel fibres and even timbers.

Bioinformatics is another complementary domain, cutting across biotechnology related activities and has become an important tool for closer collaboration among biotechnologists and advancing further biotechnological know- how.

Biotechnology offers less dependence on agro-chemicals and potential for more sustainable methods of plant production and protection. It creates conditions, which would enable developing countries to take full advantage of investing scarce human and financial resources in biotechnology research.

Biotechnology in developed countries include increasing productivity sustainably, reduced need and reduced costs for agrochemical inputs, rapid mass propagation of disease–free plants, tissue culture, saving time and costs when compared to conventional breeding, and more effective vaccines in animal husbandry.

Mauritian context

Biotechnology can be considered however as an emerging technology in the Mauritian context that has not yet crossed the frontiers beyond tertiary and research institutions, to leap into bio-industrial development. Yet biotechnology has far reaching prospects in Mauritius in the long term, provided a research pool of scientific knowledge, skills and expertise are developed and sustained over the next decade. New demands triggered by environmental degradation and climate change, in conjunction with population growth, may well provide an added impetus for the application of biotechnology to food and food crops in the future.

4. Current State Assessment

4.1 International Context

The “Green Revolution” technologies were mainly carried out by public research institutions and charitable foundations. In contrast, the development of agro-biotechnology in developed countries is led by multinational agro-chemicals and seeds companies, which have invested heavily in setting up in-house research facilities, commissioning research undertaken by new biotechnology firms, or entering into contractual arrangements with public research institutions or universities. The role of the private sector in biotechnology research, both basic and applied, has thus been considerably expanded. OECD in 1994 examined four case studies taken place in developing countries. These are illustrated below: -

4.1.1 Case studies

Case study experiences in developing countries as carried out by OECD in Colombia, Costa Rica, India and Zimbabwe have been examined.

In these countries research efforts have focussed primarily in the public sector, in newly established biotechnology institutes, with insignificant private sector participation, although efforts are being made to develop public/private sector collaboration. Countries have been gradually incorporating biotechnology in university curricula but for higher degrees overseas training is common.

A number of innovative examples of efforts involving the private sector and creation of markets for biotechnology products have emerged. These include tax exemptions and access to credit for local start-up companies. Government assure an initial market for these firms, the provision of large-scale testing facilities or quality control services, and efforts to seek commercial partners as soon as research results appear promising.

Collaborative arrangements between public research institutions in developing countries and commercial companies (both domestic and foreign) are receiving technical support linking biotechnology research with transferred development, where some elements of the technology, or specific research techniques, are “transferred” from developed-country laboratories to developing country.

Research techniques include genes, or products over which companies hold intellectual property rights. To date, a number of such techniques, or elements of technology, have been ‘donated” to developing countries by multinational corporations through nonexclusive, royalty-free licences; examples include introduction of insect-resistant genes in potato and sweet potato, stem-borer resistance in maize and Indo-Swiss collaboration in biotechnology for B.t-based insecticides.

One thousand and thirty six companies were employed in the “life sciences sector” in Europe in 1997, employing more than 39,000 people directly, with revenues of $ 3.1 billion and $2.2 billion invested in R&D. In 1998, US companies invested $9.9 billion in R&D, secured 153,000 people and posted total revenues of $18.6 billion (OECD). As for Canada, it had more companies in biotechnology by 1996 than either the US or Europe and, in absolute terms, more companies involved in agro-foods.

Biotechnological processes are improving and can now compete with other technologies. They are being widely used in the chemicals industry, pulp and paper production, textile and leather, food processing, metals and minerals, and energy. In developed countries, these sectors account for between 30 and 50 per cent of all manufacturing. Biotechnological processes have helped them to improve their sometimes-poor environmental image and, in many cases, increased their efficiency.
Many health and environmental applications either are now or will become success stories, scientifically, technologically and financially. In the US, for example, according to a recent industry estimate, over 80 biotechnology drugs either are or are about to come on the market. In agriculture the combination of rising population and

decreasing productivity growth rates clearly suggests the long-term need to apply modern biotechnology to crop and forage plants and to the conservation and storage of food.

The roles played by the public and private sectors, and the balance between the two, are evolving. Estimates of expenditure on agricultural biotechnology research vary widely. For the United States, a figure of $234.2 million for total Federal funding of agricultural biotechnology was quoted in 1994. For all International Agricultural Research Centres (IARCs) combined, in 1993 an estimated $23.6 million was devoted to biotechnology research.

A few developing countries (India, Colombia, Kenya, Mexico, Thailand and Zimbabwe) are fast moving forward in biotechnology.

4.1.2 Environment Friendly Biotechnolological Methods Currently in Use

Biopesticides

These constitute of living organisms that eliminate agricultural pests by:

(i) Being target specific and do not destroy beneficial organisms; and
(ii) Do not leave harmful residues.

Examples of biopesticides include:

1. Trichogramma (egg parasitoid) for control of Lepidopteran pests such as sugar cane internode borer;
2. Fungi (Trichoderma & Glicodadium) for control of root rot and wilt disease in tube crops;
3. *Bacillus thuringiensis;*
4. Neem extracts; and
5. Baculoviruses – e.g Granulosis virus (GV) for sugar cane internode borer.

4.1.3 Intellectual Property Rights

Most biotechnologies are intellectual properties. The challenges facing legislators have not been made easier by the public's unease about health and safety. One such reason lies in the confusion between material property rights and intellectual "property" rights, which are in fact temporary rights of exclusive exploitation of an idea and not ownership rights to the product that emerges from it. Patenting give ownership rights to, for example, the genetically controlled process leading to a new life form, but in no way does the patent confer ownership rights on the life form itself. Patenting also protects new ideas and acts as an incentive for scientists to continue research. Access to many technological or intellectual properties requires that institutions and countries meet certain legal and biosafety requirements. Specific policy guidelines include:

- Intellectual Property rights (Plant Breeders Rights or patents).
- Biosafety regulations and monitoring.
- Novel food regulations.

4.2 Mauritius Context

4.2.1 Vaccines

The Animal Health Laboratory produces vaccines against Newcastle Disease and Fowl Pox in small amounts basically to meet the needs of small and medium breeders.

4.2.2 Plant Biotechnology

The private sector is involved to a very limited extent, in the commercial propagation of horticultural plantlets. This sector is more involved in mass propagation of tissue plantlets of Anthurium. Anthurium research is conducted mainly by the Ministry of Agriculture and Natural Resources.

Micropropagation of endangered endemic plants, confined to some endemic orchids for the time being are also ongoing.

Sugar cane plantlets propagated by tissue culture are the areas of focus of the Mauritius Sugar Industry Research Institute (MSIRI).

4.2.3 Regulatory Framework

There is an absence of specific legislation covering Biosafety and Bio-ethics. The same applies for intellectual property rights with respect to patented rights in the field of genetic engineering, biomedicine and animal vaccine.

Presently there is a draft document on genetically Modified Organisms under review by the State Law Office of Mauritius.

5. Constraints and Challenges

5.1 Constraints and Challenges in Developing Countries

Moving from the purely research phase to development (small-to large-scale) through field testing, setting up of a pilot plant and seed multiplication among others, appears to be a major constraint in developing countries. This is in part because development is not always included or is often underestimated, or both, in research budgets.

Inadequate attention has been paid to technology diffusion or marketing mechanisms or to the demand side aspects of biotechnology. Without the incentive of strong market potential, private firms are unwilling to undertake the risks of production and marketing.

Public research institutions are shown to be ill equipped technically and do not generally have the financial resources to scale up from small to large scale testing, and from pilot plant to large-scale production.

The case of biopesticides presents a contrasting picture. Some governments are involved in trying to promote the diffusion of biopesticides to reduce dependence on agro-chemicals; and research in biopesticides is being supported in public institutions.

Few biotechnology products are yet on the market in developing countries. Disease-free planting material produced by tissue culture and micropropagation is already available, usually marketed by commercial firms. In some cases, demand exceeds supply.

5.2 Constraints in Mauritius

Constraints hindering the development of biotechnology arise partly due to the isolation and inadequate exposure of local scientists with the world scientific and technological community. Secondly, legal framework for promoting innovation and product protection through patents is absent. Novel processes require capital expenditure and engineers or industrial designers trained in the relevant biological processes. There is inadequate or even complete lack of motivation and incentives to enable young scientists to move forward professionally in the field of biotechnology in Mauritius.

Breeding new plant varieties require significant investment in terms of professional skills, physical and financial resources, and time. An immediate and number one concern for any country embarking in biotechnology research and trade is the development of national biosafety legislation and guidelines to take care of issues such as safe handling of transgenic materials in laboratories, greenhouses and fields. Developing countries having biosafety guidelines include Egypt, India, Colombia, Indonesia, and Kenya.

Presently the Tissue Culture Laboratory at Barkly Experimental Station (Mauritius) is a small part of the Horticulture Division of the Ministry of Agriculture. As such, it has shown its severe limitation in the translation of lab scale operations to large scale, due mainly to administrative/technical and other constraints. The laboratory needs to be integrated into a fullfledged Biotechnology Division for an efficient interface between the Ministry and the planting community so as to cater for all Biotechnology related issues including GMO Regulatory issues. The Food and Agricultural Research Council has set its biotechnological priorities within a set time frame, and end up with a strategic plan that attempts to avoid overlapping biotechnological research activities.

5.3 Challenges for Mauritius

Within the context of crop biotechnology, cash crops such as sugarcane and Anthurium are the most promising in the short term.

5.3.1 Sugar cane Industry

Biotechnology research development perspectives for the sugarcane industry are strong, as Mauritius has an excellent infrastructure and laboratory facilities for modern biotechnology methods for sugarcane improvement, and use of by-products for commercialisation. This is a present undertaken by the Mauritius Sugar Industry Research Institute (MSIRI).

5.3.2 Anthurium Industry

The Anthurium Industry can be sustained provided the threats that confront it are being challenged through high-tech research studies, transmission of the research results towards methods for mass propagation and subsequent market intelligence study. Biotechnology such as Genetic engineering and induced mutation by irradiation should become integral part of prospective research studies for the development of newly derived anthurium traits.

5.3.3 Poultry Vaccine and Animal Diseases

The country spends significantly in foreign exchange on the importation of vaccines for poultry and animal diseases. The poultry industry particularly is highly promising. Potential for export in the SADC and Indian Ocean Rim regions for meat and meat products.

To achieve meaningful results, there is a need for the provision of support measures such as development of technical-know-how beyond the threshold level, and, secondly in the initial stage, the establishment/strengthening of laboratories for biotechnology. Mauritius can serve as nucleus towards production of viral vaccines. These can be developed in due course at the National Center for Biotechnology. The physical facilities and infrastructure of the Animal Health Laboratory of the Division of Veterinary Services, Reduit should be strengthened to initiate high technology work on viral vaccine for the poultry industry. This Center should also serve as nodal point for epizootiological study, to know the status of different animal diseases prevailing in Mauritius and Rodrigues.

5.3.4 Molecular Diagnosis

5.3.5 Bioprospecting

Microbial diversity, which represents some 50 percent of all living protoplasm on earth, comprises bacteria fungi, algae and protozoa. Less than 1 percent of all these species have been characterized and can be cultured in the laboratory. Despite the importance of soil biodiversity to life sustaining processes, little is known on the important groups of microorganisms, which play major roles in these types of ecological processes. Moreover, more than 3000 antibiotics and other top-selling drugs are derived from microorganisms.

Microbial biodiversity is in fact a potential goldmine for biotechnology. It is therefore not surprising that multinationals are bioprospecting for microbes all over the globe with a view to tap on a vast biotechnological potential of microorganisms. Examples exist where microbes isolated in developing countries are being utilised by companies without any reward to the country of origin.

Hence, it is essential to build up indigenous capacity to utilise modern tools to explore the Mauritian environment for microbes with useful properties. This would be an important step for the genetic resources found in the Mauritian terrestrial and marine ecosystems to be the legal property of the country.

6. Institutional and Infrastructural Framework.

6.1 Current Status

At present excluding one of two companies in the private sector for mass propagation of imported Anthurium plantlets, it is mainly the public sector which is undertaking reserve in crop biotechnology (sugar cane, Anthurium, orchids endemic plants, strawberry and pineapples). Infrastructure at the Ministry of Agriculture and Natural Resources for plant biotechnology include the following:-

- Completely functional tissue culture laboratory for Anthurium – 220m^2 and Acclimatization facility – 180 m^2. Extension to laboratory of 183 m^2 (including 2 culture rooms of 32 m^2 each) and a new acclimatization facility of 300 m^2 is under way situated within the precincts of a major seed and plant propagation center (Barkly Experimental Station).
- Functional laboratories and green houses exists at the MSIRI for sugar cane research studies.
- Functional laboratories at the UOM are located at the faculty of Agriculture and the Faculty of Science.
- Functional laboratories exist at the FARC.

- Limited laboratory functional facilities for poultry vaccines development exist at the DVS.
- Limited mother plant repository of Anthurium and orchids.
- Custody of endemic plants within the Ministry (Forestry, National Parks).
- Institutions involved with biotechnological research include: the University of Mauritius, the Ministry of Agriculture and Natural Resources, the Mauritius Sugar Industry Research Institute and very few private companies.
- The Food and Agricultural Research Council also has laboratory and greenhouse facilities for tissue culture.
- Mauritius Sugar Industry Research Institute - Lab and biocontainment facilities.

6.2 Proposed Measures.

6.2.1 Creation of a National Biotechnology Centre.

6.2.1.1 The setting up of a Biotechnology Networking Centre

The setting up of a Biotechnology Networking Centre is to act as one stop shop for all Biotechnology related issues falling within the mandate of the Agriculture Ministry. The Ministry of Agriculture has revived the National Biotechnology Steering committee. The terms of reference for the recruitment of a consultant have been finalized and the time – frame set for an in depth analysis of the crop biotechnology areas of activity is March 2002.

The following is a breakdown of themes in biotechnology that should be focussed upon in the years to come:

- Plant Biotechnology
- Endemic Plants
- Cash Crops
- Animal Biotechnology
- Food Biotechnology
- Medical Biotechnology
- Marine Biotechnology
- Environmental Biotechnology
- Microbial Food Biotechnology.

6.2.1.2

Creation of such a Centre will allow the introduction of molecular biology to cover aspects such as genetic engineering, germplasm characterisation, disease indexing in relation to clonal propagation and germplasm conservation of horticultural crops and endemic plants among others.

Under Plant Biotechnology, focus at UOM will be on the screening of active secondary metabolites from indigenous plants; other aspects will include the use of tissue culture as a tool to enhance and optimize biologically active substances; germplasm rescue of endemic orchids; and investigations of indigenous essential oils.

Within the context of cash crops, research emphasis at the respective institutions previously mentioned, will be laid upon the enhancement of Anthurium quality for export, sugar-cane improvement; potato and tomato for local requests; and papaya (for meeting the need of tourism sector); strawberry, pine apples and bananas.

6.2.2 Human resource capacity development

At present the institutions involved have to the maximum a dozen professionals and twenty technicians. The nodal Centre excluding the network with the other biotech arms will necessitate immediately the recruitment of six to ten senior scientists and research development officers. All need to have postgraduate qualifications – Biotechnology biased, Molecular biology, Genetic engineering etc.

Provision for specialized short and long-term training in appropriate field for current staff and future intake. Recruitment of technical and support staff.

7. Research Areas

The committee identified the following projects

7.1 Cash Crops

TOPIC 1: Study of the Anthurium Industry

Objective

The objective of the project is to carry out an evaluation of the Industry.

Background and justification

The Anthurium Industry with exports of about Rs. 125 million (US$ 40.0M) appears to be stagnating as judged by the export figures for the period 1995-99. Probable reasons can be ascribed mainly to non-renewal of the “palette” of plant varieties and entrance of new competitors.

A thorough evaluation of the Industry is justified through a SWOT (Strength, Weakness, Opportunities, and Threats) analysis.

Proper identification through intelligence studies will help to identify, consolidate existing markets and prospect new export markets. This process will also help determine the varietal composition of our plantations that in turn will dictate the biotechnological thrusts to be applied. This process will also help to build a new brand of farming community to see that can develop the land released for sugar cane cultivation.

Methodology

This study may be carried out through a survey of all production parameters through questionnaires to all the stakeholders of the industry followed by round table discussions.

Proposed researchers/Institutions

AS, AREU, FARC, MEDIA.
Stakeholders: APEXHOM (Breeders/planters), Other planters
Assignment as per institutional mandate and individual expertise.

Estimated time frame: 3 months

Estimated costs: (to be worked out)

Expected outcome:

- This research will allow researchers and the government to assess about the status of the *Anthurium* industry and prospects for Research and Development at commercial scale.

- The research will also recommend for varietal composition of our plantations, renewal needs, extent of newly bred lines and associated need of breeder's rights.

Beneficiaries

The planting community and the state.

7.2 Floral Biotechnology

TOPIC 2: In vitro Clonal propagation of Anthurium

Objective

Since new planting material in terms of varieties or cultivars will be introduced for the industry, experiments will be carried out to determine the most appropriate *in vitro* propagation protocols.

Background and justification

As per the anticipated findings of the main study on the status of the Anthurium industry, (Topic 1)

- In vitro clonal propagation projects will be initiated on the relevant planting material whether imported and local.

- Import of elite planting material and its characterisation by conventional and molecular methods will be initiated prior to performance testing and eventual propagation.

- A similar approach will be adopted for locally produced parent lines/varieties. The final aim is to obtain a pool of germplasm for production as well as further breeding work.

Methodology

This study may be carried out through design experiments to find media composition that elicit the best response in terms of efficiency of propagation.

Proposed researchers/Institutions

AS, AREU, FARC, UOM.

Estimated time frame: 3-4 years

Estimated costs: To be identified in terms of purchase of elite planting material and associated royalties.

Expected outcomes:

- The clonal propagation protocol of each elite line identified for mass propagation will be available.

Beneficiaries

All Stakeholders of the Anthurium Industry.

TOPIC 3: Creation of a germplasm bank via in vitro clonal propagation and long term breeding programme for Anthurium

Objective

Breeding of new varieties/cultivars/lines

Background and justification

- The Mauritian “label” already exists and creation of new varieties will help to revamp the Industry by addition of a strong marketing point in terms of novelty. Selection of imported planting material and random or scientifically based crossing over time has led to the constitution of a genetic pool that needs to be tapped.

- Conventional and non-conventional breeding should be contemplated.

- A breeding program to be financed by the European Union was prepared by APEPA and APEXHOM (the associated of a majority of Anthurium growers). The project was unfortunately shelved for unknown reasons.

Methodology

Foreign expertise should be enlisted in this field so as to make maximum headway within a few years with this long-term project.

Genetic engineering and induced mutations by irradiation should be a prominent feature in the terms of reference of the expert (s).

Assessment of the capability of these new techniques to produce the new desired traits should also be considered.

As an essential ancillary feature to the above project, germplasm characterisation and indexing by techniques involving molecular biology will have to be developed.

Proposed Researchers/Institutions

Centred within the agricultural services with delegation of responsibilities to resource persons in their respective institutions. Where no facilities are available in the country to enlist help from centres of excellence, South-South technology transfer must be envisaged. The University of Mauritius should be able to provide synergy to this project with the help of existing staff and development of an MSc/PHd graduate scheme for the Anthurium industry.

Estimated time frame: 2-3 years for expert.

Estimated costs

Expected outcomes

Beneficiaries

The researchers, the planting community and the State.

TOPIC 4: Use of Tissue culture for the production, enhancement and optimization of bioactive secondary metabolites

Objective

The objectives of the project are:

- To use tissue culture techniques to establish producing cell lines of active secondary metabolites;
- Use and develop modern biotechnical techniques to enhance and optimise the production of active secondary metabolites;
- Use of biological assays to evaluate the potentiality of prophylactic agents produced; and
- Set up a framework for the initiation of active metabolite producing cell lines and use various strategies (physical, physiological and biotechnological) to enhance and optimise the production of biologically active secondary metabolites such as polyphonolics, terpene derivatives and alkaloids.

Background and justification

Since the establishment of basic tissue culture techniques in the early 1930's, a large number of substances have been reported to be produced by cell cultures. This system has proved to be very convenient and efficient for the study of both the biosynthesis and accumulation of compounds known as secondary metabolites. A direct application may lead to the large-scale production of substances normally synthesised by plants. This new avenue seems interesting for various reasons including climate-independent production. Moreover, the conditions involved in determining or stimulating any variation in phenotypic expression may lead to the production of novel molecules originally absent in the plant and eventually substances not screened in any plant analysed so far. More recently, new perspectives have emerged with the utilization of cells cultured in vitro as "biological reactors" able to bio-transform precursors originally not of prime importance or bearing little economic value into highly value added products. These semi biologically synthesised molecules can even allow the production of substances so far unknown.

Methodology

Initiation of producing cell lines (callus, cell suspension, root cultures) from selected Mauritian species.

Comparative studies of cell lines induced from different explants.
Modification of culture parameters.
Incorporation of precursors.
Inducing transformed root cultures by the use of Agrobacterium thumefaciens and Agrobacteriun rhizogenes strains.
Analysis of extracts.
Evaluation of biological activities.

Proposed researchers/Institutions

UOM, (Mauritius Research Council solicited grants);
Manpower – Research Assistants, MPhil/PhD students; and
Equipment and consumables.

Estimated time frame: 3 years

Estimated costs: Rs. 2,000,000

Expected outcomes:

- Determination, after stabilisation of a particular cell line (callus, root and suspension cell cultures), the respective proportion an activities of the most significant secondary metabolite classes.

- Comparison of the secondary metabolite contents of cell cultures derived from a particular cell line within themselves (callus, root and suspension cell cultures) and with parent plants from which they were induced

- Screening of the best tissue producing of bioactive secondary metabolites (precursor feeding, elicitation, transformation using bacterial strains etc……)

Beneficiaries:
Biotechnologists and Farmers

7.3 Animal Biotechnology

TOPIC 1: Production of poultry vaccines and surveillance of animal diseases

Objective:
The long-term objectives are:

- To develop technical know-how of the resource persons of the country in the area of vaccinology and Epizootiology.

- To enable Mauritius to become self reliant in its vaccine requirements for certain specific diseases.

- To make the viral vaccines produced from the local viral isolates confer better immune response than imported strains which may also introduce new pathogens in the country.

The objective of the present project is to undertake:.

- Produce infectious bursal disease (Gumboro disease) vaccine, Fowl pox and Newcastle disease vaccines on a large scale.

- To develop a systematic system to assess the annual status of Animal diseases of Mauritius.

Background and justification

Mauritius has a highly promising and enterprising poultry industry. The vaccine requirements are colossal and most vaccines are currently imported. Vaccines against other diseases namely Infectious Bursal Disease (IBD) Marek's disease and Reoviral infectious are all imported. Large industrial farms also import Newcastle disease vaccines. As regards IBD which is a disease causing economic losses exceeding 70 million rupees annually, vaccines containing several strains have been imported. However, the response has been variable and there is some evidence that the vaccinal strains may not be providing adequate protection to the birds. Trials with vaccines manufactured form local stains are giving encouraging result.

Seen the high prevalence and the economic importance of poultry diseases, it is proposed to establish/strengthen some laboratories.
The project is not only an economically viable proposition but it will boost technical know-how of resource persons to deal effectively with emergency situations regarding outbreaks of exotic diseases.

Methodology

1. **Development of Human Resource**

(a) Training on Animal tissue culture technology
(b) Training on vaccine technology
(c) Training on Epizootiology of different diseases
(d) Sponsoring M Phil studies

2. **Strengthening/upgrading the existing facilities**

a) Purchase of equipment
b) Purchase of bioreagents
c) Purchase of plastic wares and glass wares

3. **Development of viral vaccines**

   a) Development of tissue culture based IBD vaccine
   b) Large scale production of NCD and Fowl pox vaccine
   c) Development of killed vaccine

4. **Testing of vaccine**

a) Potency testing
b) Safety testing

5. **Release of vaccine**

a) For small breeders
b) For large commercial farms

Proposed researchers/Institutions

Mauritius Research Council, Animal Health Laboratory, DVS, Ministry of Agriculture, FT & NR, University of Mauritius, Overseas Consultants

Estimated time frame: 3 years

Estimated costs

Financial

i.	Training of resource persons	1.5
ii.	Sponsoring of 2 MPhil projects	2.0

Manpower

NIL	-

Equipment

i.	Freeze dryer & its maintenance	15
ii.	Ultra deep freezer & its maintenance	2.5
iii.	Large size incubator	2
iv.	Personal computer	0.5
v.	Material & supplies	2.0
vi.	Travelling & office expenses	1.5

Expected outcomes

The project will develop expertise of resource persons in areas of:
(a) tissue culture
(b) serology
(c) immunology
(d) isolation, characterisation and identification of viruses from clinial cases
(e) vaccine technology
(f) creation of vaccine production centers.

Beneficiaries

(a) Small Poultry breeders
(b) Big Commercial poultry farms
(c) Animal Health Laboratory, Ministry of Agriculture, Food Technology & Natural Resources
(d) Mauritius Research Council

7.4 Medicinal Plants

TOPIC 1: Validation of the commonly used medicinal plants according to existing protocols

Objective

The objective of the project is to provide low costs medications to the public at large.

Background and justification

During the past decade, traditional systems of medicine have become a topic of global importance. Current estimates suggest that, in many developing countries, a large proportion of populations relies heavily on traditional practices and medicinal plants may be available in these countries, herbal medicines (phytomedicines) have often maintained popularity for historical and cultural reasons. Concurrently, many people in developed countries have begun to turn to alternative or complementary therapies, including medicinal herbs.

Few plant species that provide medicinal herbs have been scientifically evaluated for their possible medical application. Safety and efficacy data are available for even fewer plants, their extracts and active ingredients and their preparations containing them. Furthermore, in most countries, the herbal medicines market is poorly regulated and herbal products are often neither registered nor controlled. Assurance of the safety, quality and efficacy of medicinal plant products has now become the key issue in industrialised countries and in developing countries. Both the general consumer and health-care professional need up-to-date, authoritative information on the safety and efficacy of the medicinal plants.

For Mauritius, this is also in line with the Government/Private Sector policy as established in their joint vision in the document 'Economy in transition' published in November 2000.

Methodology

1. Rationalising the most popular and commonly used medicinal plants as per exiting literature
2. Validation of their ethnobotanical information using existing protocols
3. Advanced tests on the plants (phytochemical, pharmatological, toxicity etc…..)

Proposed researchers/Institutions

UOM, MoHealth, MoAgriculture
Human resources: 2 Research Assistants (preferably at MSc level)

Estimated time frame:

Estimated costs: Rs 600,000

Expected outcomes
Provide cheap and safe medications to the public at large.

Beneficiaries

TOPIC 2: Production of essential oils from the locally available aromatic plants.

Objectives

The objective of the project is to exploit the local flora for the production of essential oils.

Background and justification

The demand for essential oils/oleoresins on the word market is on the increase. Mauritius is probably the only island in the indian Ocean where we have not yet established a culture for the production of essential oils. Attempts so far have been very timid and nonetheless, the returns have been encouraging. Many plants grow in Mauritius and which could potentially be exploited for the production of essential oils. There is a growing demand for new oils for industries like aromatherapy, the food industries, and pharmaceutical and cosmetic industries amongst others.

This project will have its role to play in the new agricultural diversification programme.

Methodology

1. Carry out a feasibility study on the locally growing aromatic plants.
2. Advanced pharmacological testings of the oils
3. Pilot scale production for some of the selected oils

Proposed researchers/Institutions

UOM, MoAgriculture, Private Sector
2 Research Assistants (preferably at MSc level)

Estimated time frame:

Estimated costs: Rs 500,000

Expected outcomes

Produce value-added products that will fit in the agricultural diversification programme.

Beneficiaries

TOPIC 3: Screening, Extraction, Identification and Purification of active Secondary metabolites from Mauritian Endemic plants and their Assessment as potential prophylactic agents.

Objective

The objectives of the project are:

To set up a new framework and to develop existing infrastructure to obtain interesting bioactive secondary metabolites from selected Mauritian endemic plants

To determine and evaluate biological properties of total and fractionated in vivo plant extracts or individual isolated molecules (antioxidant, free radical scavenging, antimicrobial, antihelminthic, etc.)

Background and justification

Mauritius and its islands harbour a relatively wide variety of endemic plant species among which many have been classified as endangered. Many of these plants, containing active secondary metabolites, have been used as folk medicines since many years without any precise knowledge about the specific substances responsible for their beneficial action. Among the plant secondary metabolites, terpene derivatives including essential oils, alkaloids and their derivatives and polyphenolic compounds are the main classes that have been reported to exhibit a wide range of biological effects including antibacterial, anti-inflammatory, antiviral, antiviral, antiallergic, antcarcinogenic, antitumoral, antifungul, cardioprotective actions, antioxidant and free radical scavenging activities. Preliminary research work conducted at the University of Mauritius on a number of endemic species (Syzigium, Monimiastrun, Eugenia, Trochetia etc….) have already shown the presence of the above mentioned classes of compounds. In this project we propose to develop a framework to carry in depth analyses to characterise total and fractionated extracts or individual substances from selected endemic species and show their prophylactic potential using various assay systems against the above mentioned disorders.

Methodology

1. **Plant material**

- Whole *in vivo* fresh plants or particular organs/tissues at specific vegetative stages (leaves, stems, flowers, fruits, seeds, barks, roots)

2. **Substances studied**

- Polyphenols: (phonolic acids, anthraquinones, flavonoids, anthocyanins (red colorants), flavan-3-ols derivatives
- Terpenes and derivatives (monoterpenes, diterpenes, sesquiterpenes etc…)
- Alkaloids and derivatives
- Other secondary metabolites classes of biological and economic interest

3. **Types of extracts**

To correlate biological activities with studied structures or groups of compounds it would be necessary to prepare from the above mentioned plant tissues:

- Total extracts
- Fractionated extracts or enriched fractions
- Targeted fractions comprising one particular group Extracts containing isolated molecules (for structure determination and/or biological activity)
- Extracts containing standard molecules not available commercially for analyses and biological activities assays

4. **Biological activities**

Total, fractionated extracts and/or isolated molecules will be assayed for:

- Antioxidant and free radical scavenging activities
- Antibacterial activities
- Antifungal activities

These assay systems are available at the University of Mauritius. Other assays systems (antihelmintic, antielastase, and antiprotease) need to be implemented with the help of collaboration international institutions.

Proposed researchers/Institutions

University of Mauritius
Mauritius Research Council
The Mauritius Herbarium

Estimated time frame: 3 Years

Estimated costs: 2,500,000
Equipment – Complete Preparative Chromatography equipment, HPLC columns, consumables

Expected outcomes

- To extricate a vegetative stage, organ (leaf, flower, seed, root, etc.) or a specific tissue favouring the synthesis and accumulation of bioactive secondary metabolites with a view to enhancing the plant value.
- Determination in the selected tissues the respective proportion and activities of the most interesting chemical groups.
- Isolation of standard molecules not available commercially from high content plant sources

Beneficiaries

7.5 Microbial food biotechnology

Topics 1: Promotion of Anaerobic Biotechnology

Objectives

- Characterise the potential and limitations governing the applicability of anaerobic biotechnology to the treatment of liquid and solid wastes in the Mauritian Context.

- Review the application of Anaerobic Digestion for the following sectors: domestic sewage, industrial wastewater and organic solid wastes.
- Make recommendations per sector
- Run two demonstration projects (one in liquid waste and one in solid waste) and facilitate know-how exchange

- Design of a criteria catalogue to help institutions/industries identify the methods of treatment for domestic and industrial wastewater and organic wastes that are most appropriate for their own particular situation.

Background and justification

Apart from agriculture, where millions of anaerobic digesters have been installed all over the world, anaerobic digestion has most been applied for the treatment of wastewater from **agro, food and beverage industries**. Anaerobic digestion is also increasingly being applied for **domestic wastewater treatment** in tropical countries. Another field of application is emerging so far only in developed countries. Several full-scale treatment plants for **municipal solid wastes** have been built in the last years, specially in countries where source separation of domestic waste has already been implemented. These plants often consist of a combined system of anaerobic digestion and composting.

A lot of research is being done on new fields of application for anaerobic digestion. **Anaerobic digestion is considered as a sustainable treatment technology as it combines both the goals of environmental production and energy production.** Today this technology is also increasingly being used for several other industrial branches like chemical, petrochemical, pharmaceutical industries etc. There are several anaerobic systems adapted for different treatment purposes, sites, climates and technical levels.

Though not widely spread, anaerobic biotechnologies for liquid and solid wastes of industrial and domestic origin will prove to be an effective, economical and energy conserving alternative to standard treatment methods. However, systematically compiled and evaluated criteria are still lacking as a basis for decisions concerning appropriate application of anaerobic biotechnology.

Methodology

- Review and assessment of anaerobic biotechnology (3 months)
- Construction and operation of two pilot-demonstration projects (2 years)
- Dissemination of findings and organisation of Seminars (3 months)
- Design of Criteria Catalogue (3 months)

Resource Requirements

Human	:Dr T. RAMJEAWON
	:Dr R. MOHEE
	:2 Research Assistants (recruited over a period of two years)
Equipment	:Construction of two anaerobic pilots plants (approx. Rs 1 million)
	:Monitoring equipment (approx. Rs 500,000).
Financial	:Approx. Rs 2.5 million
Institutional	:University of Mauritius, MRC, and Ministry of Local Government, Private Sector.

Expected Results:-

A. Preservation of the Environment and Resources:

Lower emission of methane gas and CO_2, and hence less global warming (greenhouse effect); less consumption of fossil energy sources; use of treated wastewater; digested sludge and compost in agriculture for purposes of irrigation and as organic fertilisers; improved hygiene.

B. Macroeconomics:

Improved living conditions and long-term economic development through resource conserving treatment of liquid and solid wastes, with reduction of macroeconomic costs through the exploitation of renewable energy sources.

C. Microeconomics:

Analysis and consultancy inputs for the design of new facilities and optimisation of existing facilities.

D. Socio-cultural:

Improved consideration for environmental issues due to awareness- raising measures in the form of consultancy inputs and seminars.

7.6 Environmental Biotechnology

Topic 1: Enrichment of compost produced from the organic portion of municipal solid waste with nitrogenous additives.

Objectives

- Investigate about large-scale composting of municipal solid waste.
- Determine quality of compost derived from the organic fraction of municipal solid waste,
- Investigate the effect of animal manure, urea addition during compost process and nutrient content in finished compost(an enriching process)
- Pelletise the compost for better handling and storage
- Effect of the enriched compost on plant trials with reduced fertilisers rates

Brief Background

During the last few years, composting has been viewed more as a means of waste disposal than using the humus like product for agricultural purposes. Nowadays due to increasing environmental concerns and the problems such as plant diseases, loss of soil fertility and lack of manure in the country, compost utilisation is gaining in popularity, provided it is of good quality. As such, it is essential to promote composting as a practice and the use of compost in agriculture to establish recycling systems for resource circulation and to achieve sustainable agriculture.

Methodology

Large-scale composting of municipal solid waste will be conducted at a convenient place such as an existing transfer station. The compost produced will be analysed.
Chicken manure and/or Urea will be added at the start of the composting process and the different parameters affecting the process will be monitored. A comparative study of the composting process and compost characteristics will be undertaken for municipal solid waste without nitrogen additives. Various tests will be carried out on the compost to determine its maturity and its nutrient content.
The compost produced will be pelletised. Different additives to bind the compost will be investigated. Both compost and compost pellets will be used in plant trials with the aim to partially reduce fertiliser requirements.

Resource requirements

Human:	Dr R. Mohee from UOM 1 representative from AREU 1 Research Assistant for two years
Equipment:	Solvita test kit, chemicals for carrying out various tests such NPK, sieve and pressing device. Concrete slab for windrow construction.
Institutional support:	UOM (AAS from Chemistry department or Faculty of Agriculture), Ministry of Local Government, AREU

Time Frame

Two years: Phase I: Production of composts on large scale
Phase II: Analysis of compost

Expected Results

Produce enriched compost that could partially replace chemical fertilisers.
Production of compost pellets for ease of handling and storage
Sustainable method to treat solid wastes.

ANNEX:

Annex 1: Composition of Working Group

Chairman	Prof. S. Bhoojedhur, Mauritius Research Council

Members

Dr T Bahorun	Senior Lecturer, University of Mauritius
Dr (Mrs) Gurib-Fakim	Associate Professor, Faculty of Science, University of Mauritius
Mr N Gopaul	Ag Senior Research & Development Officer, Ministry of Agriculture, Food Technology and Natural Resources
Dr G Khittoo	Associate Professor, University of Mauritius
Assoc Prof R Mohee	Associate Professor, University of Mauritius
Mr D Puchooa	Senior Lecturer, Faculty of Agriculture, University of Mauritius
Dr T Ramjeawon	Associate Professor, Faculty of Engineering, University of Mauritius
Mr J Ramkissoon	Director, Food and Agricultural Research Council
Dr (Mrs) A Saumtally	Head, Biotechnology Department, Mauritius Sugar Industry Research Institute
Prof R N Srivastava	ITEC Expert Virology (Counsellor), Division of Veterinary Services, Ministry of Agriculture, Food Technology and Natural Resources

With the participation of

Dr A. Suddhoo	Executive Director, Mauritius Research Council

Co-ordinator

Mrs P Doman, Mauritius Research Council

Annex 2*: List of completed/ongoing projects in Biotechnology*

Environmental Biotechnology

(a) List of completed projects

Composting of sugar cane by products. MRC funded project

Beneficiary: Rose Belle Sugar Estate

Status: Completed (2000)

The physical and chemical characteristics of bagasse and filter cake were determined. Small-scale trials were conducted in drum composter for scum and filter cake. Also, windrow composting of 10 tons of sugar cane by products was developed and compost obtained was used in sugar cane fields. This study has been one of the first in Mauritius to demonstrate large scale composting.

1. **Assessing recovery potential of solid waste. MRC funded project**

   Beneficiary: Mauriclean Ltd

   Status: Completed (2000)

   A study was done in a residential area within the township of Quatre-Bornes to assess the amount and characteristics of solid waste generated. It was found that the solid waste generation rate was 1.32 kg/capita/day and there was a high proportion of organic wastes (around 80percent) in the municipal waste stream. Household composting was recommended as an appropriate solution towards waste minimisation.

2. **Composting potential of bagasse and broiler litter and Process simulation using a dynamic *model. PhD project***

   Status: Completed (1997)

   The composting potential bagasse and broiler litter was investigated. A model was developed to simulate the dynamics of co posting of bagasse and mixture of bagasse/broiler litter using the system dynamics software. With this model it was possible to determine proper control strategies for successful composting of bagasse.

3. **Organic Compost Making UNDP GEF/SGP funded project.**

   Beneficiary: National Federation of Young Farmers, Belle Mare
   Status: Completed (1999)
   The aim was to demonstrate the feasibility of composting organic waste into high quality compost using simple technologies. Both windrow technology and rotary composters have been used to compost bagasse and chicken waste. Local farmers have been exposed to these composting practices and compost obtained was used on cultivated land.

4. **Sustainable Agricultural Technologies for Rodrigues. UNDP GEF/SGP project.**

   Beneficiary: Rodrigues Council of Social Services
   Status: Completed (2000) and project extended to include more composters
   The aim was to improve the small-scale community based farms by use of environmentally friendly technologies. This was done by initiating and disseminating new practices of compost making, involving local enterprises in compost drum manufacture and training of local farmers in the art of compost making. It has been found that the rotary composter was the most appropriate for farmers in Rodrigues.

5. **Development of rotary composter for small scale composting.**

   Status: 115 composters presently used; Applied for patent in 2000
   Rotary composters have been designed and developed in order to recycle household organic waste in view of safe disposal of waste to ultimately produce compost. This type of backyard home composting reduces the bulk of organic waste in the waste steam.

6. **Recirculation of leachate to enhance degradation of MSW in landfills (Patny)**

   Three identical reactors were designed and developed into which landfill conditions were stimulated. The reactor was a flat-bottomed vertical cylindrical vessel made of HDPE plastic. Moisture content in vessels was adjusted and the waste compacted to comparable landfill level.

7. **Development of a small-scale continuous composting unit for domestic waste (Gopaul)**

   The aim of the study was to develop a small-scale continuous composter for domestic wastes. The composter was a hexagonal vessel made from locally available fibreglass mounted on shaft and bearings to ease mixing. The composter was tested with bagasse and broiler litter and compared with the rotary drum composter. It has been observed that the hexagonal rotary composter was more efficient.

8. **Forced aeration in composting scum and bagasse (Ramsurn)**

   A comparison between natural aeration and forced aeration of a composting mixture consisting of bagasse and broiler litter in a dry mass ratio of 1:2 was performed. Result showed that a high temperature and a high moisture content were observed in the natural aeration composting leading to a decrease in microbiological activity and hence a decrease in decomposition rate.

9. **Anaerobic digestion of sludge and MSW (Lobin)**

   The aim was to present and adapt anaerobic digestion technology, a well known process successfully employed in other countries, as an alternative waste management option from the simultaneous treatment of the organic fraction of MSW and waste water derived sludge in the country. Results showed that a retention time of 23 days gave the best organic removal efficiency and addition of feed richest in sludge had a beneficial effect on the process. Locally available waste material can thus be converted to a valuable source of energy and humus like residue.

10. Energy balance in a small scale composter (Mohabuth)

The aim was to investigate about the efficiency of small scale composting system. Due to its large surface area to volume ratio small scale system was found to lose greater amount of heat than full-scale system. To compensate for the heat loss, the composter was insulated with polystyrene and plywood and it was found to be comparable to full-scale system.

11. Investigating the Quality of Compost derived from Organic portion of Municipal Solid Waste (H. Rughoonundun)

The aim was to assess the quality of compost obtained from the organic portion of MSW with emphasis on the Nitrogen, Phosphorous and Potassium content and to investigate whether addition of an animal manure, chicken litter would improve the quality of the compost. The results showed that the organic fraction of MSW contains the appropriate balance of nutrients and microorganisms and would compost on its own while the addition of chicken litter significantly improved the process.

12. Predicting Leachate Generation at Mare Chicose Landfill. (B.K.Rughooputh)

The aim was to develop a water balance model for a landfill in Mauritius and taking into consideration its filling sequence as well as the effect it has on leachate flows. The results showed that though both models were able to predict leachate generation within acceptable limits, the water balance proved to be more accurate when compared to the computer HELP model.

13. A Comparative study of Anaerobic Co-digestion of MSW and Sewage Sludge at Mesophilic and Thermophilic Temperatures regime. (Dhanoopa)

The aim was to investigate the anaerobic co-digestion of MSW and sewage sludge at mesophilic and thermophilic temperatures to determine the effectiveness of anaerobic digestion for typical composition of MSW. The anaerobic digestion process was evaluated in terms of TS, VS, COD and amount of methane produced. On comparing anaerobic digestion at mesophilic and thermophilic temperatures it was found that it was less stable at high temperature, required a larger amount of energy and a lesser amount of methane was produced. However, the rate of organic matter removal at thermophilic temperature was more efficient.

(b) List of ongoing projects

1. **Develop an index for compost quality. UoM funded.**

   Research Assistant: Miss R. Gaju
   Status: Ongoing.

   The aim of the project was to develop an index for compost quality. Two types of compost namely municipal solid waste and bagasse and chicken waste are being investigated to assess their effects on plants. Physical and chemical parameters are also being investigated for quality of the compost. Based on these findings an environmental index will also be developed which will take into consideration the final use of compost whether as mulch, soil amendment or nutrient amendment.

   Plant Biotechnology

2. **Sugar Sector**

   Sugarcane

   a) Genome mapping

   Construction of genetic maps of commercial sugarcane cultivars and identification of molecular markers to disease resistance traits and agronomic characters.

   Fingerprinting of sugarcane cultivars using microsattelite markers

   b) Tissue culture

   In vitro micropropagation of commercial sugarcane varieties for the production of disease free material for establishment of nurseries.

   c) Genetic transformation

   Genetic transformation of sugarcane for herbicide resistance using the Agobacterium and biolistic systems.

   d) Diagnostic tests

   Development and use of molecular diagnostic tests for the detection and characterisation of the casual organisms of sugarcane yellow leaf virus and sugarcane yellow phytoplasma.

3. **Non Sugar Sector**

Potato (MSIRI)

Genetic transformation of local potato varieties for resistance to potato virus Y (PvY) and potato leaf roll virus (PLRV).

Production of disease free micro and minitubers from in-vitro propagated potato plantlets.
Development and use of molecular diagnostic tools for the diagnosis of major potato diseases.

Anthurium

Induced mutation in A.andreanum

Varietal identification by DNA fingerprinting

Development of molecular tools for the detection and identification of disease-causing agents (banana, potatoes, anthurium)

Annex 3: Suggested Reading

1. Brenner Carlienne (1997). OECD Development Center – Biotechnology Policy For Developing Country Agriculture. 31p

2. OECD Observer (1999). Modern Biotechnology and the OECD. 8p.