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Development of Biotechnology in Egypt

Abstract: The development of biotechnology in Egypt since 1990 is reviewed. The National Strategy for Genetic Engineering and Biotechnology is outlined and the priorities for its implementation are given. The numerous research and development activities in biotechnology under the auspices of the Ministry of State for Scientific Research, the Ministry of Agriculture, collaborative programs and eight large universities are delineated. Activities of public and private industrial units are summarized. Finally, the public—private sector collaboration experience at the Agriculture Genetic Engineering Research Institute is described.

Keywords: Egypt, Biotechnology, Genetic Engineering, Research activities, Universities, Private Sector.

Introduction

Biotechnology is widely regarded as an exciting new technology having promising applications in many areas of development and possessing great opportunities for commercial interests. Thus, it has been selected as one of a small group of key technologies singled out by the country of Egypt as worthy of special support since the early eighties.

Egypt is endowed with a wealth of qualified and experienced scientific manpower resources in many fields including those biological sciences interacting with biotechnology; i.e., genetics (plant, animal and human) biotechnology, microbiology, virology, physiology, plant and animal breeding, food technology, industrial fermentation, medical physics, biophysics, tissue culture, mammalian cell culture, cell physiology, etc.

The number of qualified staff in the above fields exceeds 7000 scientists, supported by competent

تطور التكنولوجيا الحيوية في مصر
مدحت سيف النصر

المستخلص: تهدف الدراسة إلى إستعراض مدى التطور في مجالات توظيف التكنولوجيا الحيوية على كافة المستويات في جمهورية مصر العربية طوال العقد الماضي منذ 1990 م. وذلك بالإشارة إلى الإنجازات في إستراتيجيات الهندسة الوراثية الوطنية وأولويات تحقيق البرامج القائمة على توظيف التكنولوجيا الحيوية. ويستدل على قياس مستوى التطوير، برصد الأنشطة البحثية ومشروعات التنمية المعتمدة على تطبيقات التكنولوجيا الحيوية على المستويين الرسمي والأكاديمي وتوضيح أهميتها في مشروعات التأهيل الزراعي، الصحي، الصناعي والبيئي، إلى جانب أنشطة البحث العلمي المشتركة بين الجامعات المصرية ومساهمات القطاع الخاص في هذا المجال.

كلمات مدخلية: مصر، تكنولوجيا حيوية، هندسة وراثية، بحوث علمية، جامعات، قطاع خاص.

staff. Many of these scientists have been educated in well-reputed European and American universities. They are working in research institutions and universities, mostly in topics related to conventional biotechnology, but a number of them can be drawn upon to cooperate in the research related to advanced biotechnology.

Biotechnology in Egypt has developed rapidly since 1990. Areas of successful biotechnology application include tissue culture of crop plants, genetic engineering and diagnosis of tumors. Research into the transplantation of bone marrow, kidneys and liver is still in the experimental stage.

Health awareness is on the rise in Egypt. Correspondingly, the use of biotechnology in medical research centers and universities is also increasing. The five-year plan for 1992-1997, allocated \$340 million for upgrading medical services, including the introduction of biotechnology to universities and research institutions.

The Foreign Relations Correlation Unit (FRCU), which is funded by the Egyptian government, was established in 1992 and has funded five genetic engineering grants with LE 250,000 for two to three years. Four of these grants are agricultural and one pharmaceutical. The FRCU formed the Egyptian

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University Network (EUN) between the listed centers, complete with computer access and Internet slip accounts, in order to promote communication between scientists and to facilitate the exchange of information.

The University Linkage Project, established in 1981 with USAID funding, is in phase II and is promoting Egyptian and American University collaboration for projects, with the private sector as end user of the developed technologies.

In Egypt, there are several programs which fund projects in the field of genetic engineering and biotechnology. The first of these programs is the Program of the National Strategy for Biotechnology and Genetic Engineering, which is currently funding 33 research projects in this field. These include 15 projects in agriculture, 12 in health, five in environment and 1 in industry. This program is organized through the Ministry of State for Scientific Research (MOSR).

Another program is the US-Egypt Science and Technology Joint Fund between the Arab Republic of Egypt and the United States of America. The Joint Fund is funding 44 projects in the field of Genetic Engineering and Biotechnology. These include 13 projects in agriculture, 21 in health, 5 in environment, 3 in industry and 2 in basic science. This program is organized through the Academy of Scientific Research and Technology (ASRT).

NATIONAL STRATEGY FOR GENETIC ENGINEERING AND BIOTECHNOLOGY

A national strategy for genetic engineering and biotechnology was established in Egypt with two general goals:

- To introduce Egypt to the genetic engineering and biotechnology era with the objective of improving agricultural and industrial production as well as improving product quality to be able to compete in the global market, particularly after full implementation of GATT.
- To promote private sector investment in modern biotechnology industries.

To develop a national strategy for genetic engineering and biotechnology, a team of twenty scientists from educational and research institutions under the leadership of the Academy of Scientific Research and Technology (ASRT) outlined the broad research goals for the participating institutions. This was developed into a realistic

national strategy for biotechnology through identification of specific short-term projects and long-term projects by each of the major biotechnology sectors; namely agriculture, industry, medicine and environment. Articulation of short-term and long-term goals in each sector is undertaken by a task force appointed by the Minister of State for Scientific Research (MOSR) in coordination with the ministerial committee on Science and Technology. Each task force has solicited proposals in accordance with these priorities from biotechnology centers in universities and research institutions. The proposals include a scientific outline of the project, a description of collaborative arrangements with other institutions in Egypt and abroad, an analysis of potential economic feasibility and impact, and a brief vitae that indicates the relevant expertise and publication by the principal investigator in each project. The participants include also consulting scientists and economists from abroad invited by the Ministry for Scientific Research.

APPROVED PRIORITIES FOR THE IMPLEMENTATION OF THE STRATEGY

Agriculture

Short term projects (3-5 years):

- Production of commercial plants tolerant to viruses and insects.
- Bio-fertilization with genetically modified high quality inoculates.
- Production of vaccines and therapeutic reagents for animal and fish diseases.
- Improvement of integrated pest management.

Long term projects (10 years duration):

- Production of plants tolerant to the stress conditions of salinity and drought.
- Gene mapping of the important economic crops in Egypt.
- Transfer of BNF genes to certain commercial plants.

Health

Short term projects (3-5 years):

- Production of diagnostic kits for viral diseases, tuberculosis and bilharziases as

well as tumor marker kits.

- Improvement and production of vaccines for some endemic diseases in Egypt.
- Production of some antibiotics.

Long term projects (10 years duration):

- Production, patenting and marketing of vaccines for bilharzia and hepatitis viruses.
- Production of Immuno- regulators.

Industry

Short term projects (3-5 years):

- Establishment of multi-purpose pilot plants for industrial biotechnology.
- Improvement of biotechnology-based industries by using genetically engineered organisms.
- Production of novel compounds such as biological and enzymatic reagents.
- Production of microbial rennin.

Long term projects (10 years duration):

- Improvement of the production of enzymes used in food industries.

Environment

Short term projects (3-5 years):

- Production of bio-pesticides suitable for field use.
- Development of biotechnology for pollutants degradation.
- Use of modern biotechnology for recycling of water, energy and materials.

Long term projects (10 years duration):

- Removal of pollutants from soil and water bodies.
- Use of bio-sensors for detection of pollutant levels.
- Use of genetic engineering and biotechnology tools for tracking the toxicity of pesticides.

The total budget of this strategy is 160 million Egyptian pounds. Thirty-three projects have already

been approved and financed with about 21.000.000 LE.

The National Biosafety Committee

The National Biosafety Committee was established in 1995. Its mission includes:

- Establishment of national policy and instructions for the safe use of genetic engineered organisms and products.
- Follow up of the application of biosafety roles.
- Training and consultation on biosafety procedures.

RESEARCH AND DEVELOPMENT ACTIVITIES

Ministry of State for Scientific Research (MOSR)

Academy of Scientific Research and Technology (ASRT)

The Academy of Scientific Research and Technology is the national scientific and technological body responsible for planning, support, follow-up and evaluation of research in Egypt within the framework of the national development plan.

The organization chart of the Academy includes among other sectors, the following:

- Specialized research councils (13 councils)
- Subject matter committees (46 committees including the Genetic Engineering and Biotechnology Committee).

Technology Development Sector

A scientific and cultural relations (national and international) sector.

Supporting and auxiliary service units including; Scientific Instrumentation Center; National Information and Documentation Center; Patent Office, and the National Information Network with its six science information nodes covering agriculture, health, industry, energy construction and housing, and science and technology.

In addition, the Academy has developed a national technology policy scheme of which genetic engineering and biotechnology is one of the four areas covered by the plan in its first phase of implementation.

The National Egyptian Focal Point of Genetic Engineering and Biotechnology (NEFP-GEB)

The National Focal Point of Genetic Engineering and Biotechnology (NEFP-GEB) was established in 1991 at the Academy of Scientific Research and Technology of Egypt (ASRT) to enhance basic and applied research in the era of genetic engineering and biotechnology at the national level and to encourage the release of biotechnology techniques to production and services sectors.

These objectives will be achieved through coordinating and supporting related resources and activities within the framework of a national program, as well as coordination between the national, regional and international efforts. Moreover, it assists the different institutions of scientific research, education, application and media.

NEFP-GEB represents Egypt in the International Center for Genetic Engineering and Biotechnology (ICGEB).

Biotechnology Research Program under the USAID—ASRT Science and Technology Cooperation Project.

The USAID-ASRT Project is planning supporting and evaluating research programs to be carried out by different capable research teams in the universities and research institutions. This program of biotechnology includes projects dealing with conventional and advanced biotechnology in the food and agriculture, industry, environment and human health sectors.

Support for the Inter-Islamic Network on Genetic Engineering and Biotechnology (INOGE).

The Inter-Islamic Network on Genetic Engineering and Biotechnology was established at ASRT in 1987. Twelve Moslem countries, each represented by a focal research institute or national organization, are participating in this network. Up till now there are neither subscription fees nor membership dues for this network. Its financial resources are no more than limited grants from COMSTECH and the ASRT of Egypt.

National Research Centre (NRC)

National Research Centre is the largest multidisciplinary R & D Centre devoted to basic and applied research within the major fields of interest. It is the largest of all institutions affiliated to the

Ministry of Scientific Research and employs about 70% of all scientists working in these institutions. It was established in 1956 to fulfill a main objective, which is to correspond to the country's key production and service sectors through research conducted in different areas of science and technology, scientific consultation and training.

NRC possesses an impressive scientific and technological infrastructure and manpower resources exceeding 1400 research staff. It consists of 11 divisions and 63 departments covering the major areas of industry, health, environment, agriculture, basic sciences and engineering. NRC is marked by a basic orientation of its activities to customer-oriented research in order to address the national needs more effectively through scientific and technical research.

Genetic Engineering and Biotechnology Division

The Genetic Engineering and Biotechnology Division contains the following nine departments.

Molecular Biology Department

The main ongoing projects of the Molecular Biology Department deal with enzyme production for industrial and clinical diagnosis.

Cell Biology Department

The research interest of the Cell Biology Department includes:

- Animal cytogenetics (chromosome and gene mapping in water buffalo).
- Bio-technical methods for embryo technology (embryo culture, transfer, sexing, splitting of preimplantation, freezing of embryos, twinning, and transgenic model).

Plant Cell and Tissue Culture Department

The mission of the Plant Cell and Tissue Culture Department is:

- Laboratory culturing of important economic plants.
- Genetic improvement of some economical plants.
- Production of some plants free of diseases.
- Production of some natural products of medicinal and industrial importance.

- Preservation of the genetic origin of Egyptian plants.

The ongoing research work includes:

- Semi-industrial production of potato tubers, free of virus diseases.
- Production of enzymes for medical diagnosis and industrial applications.
- Improvement of artichoke production.
- Production of tropane—alkaloids by using tissue culture techniques from Egyptian Solanaceous plants.
- Improvement of the production of natural silk in Egypt.
- Production of fava bean plants that are resistant to fungal attacks.
- Economic production of antineoplastic (anticancer) alkaloids through biotechnological techniques from Egyptian *Catharanthus roseus*.

Microbial Biotechnology Department

The ongoing research work of the Microbial Biotechnology Department includes:

- Ethanol production from sugary by-products.
- Methanol production from agri/industrial wastes.
- Bio-gas and fermentation.

Microbial Genetics Department

The mission of the Microbial Genetics Department is the application of genetic engineering techniques, which include gene identification, cloning, amplification, manipulation, recombination, transfer, DNA/DNA hybridization and transposon mutagenesis, plasmid manipulation, transfer and stability. Protoplast fusion is also included. All these techniques are used for the benefit of agricultural and industrial purposes and for health care.

Genes of interest: the current research interests include the following genes:

- Rennin genes
- Lactose-utilizing genes
- Cellulases genes
- Plant-growth hormone genes

- Bacteriocins genes
- Heavy metals resistant genes
- Plant-defense genes

Human Genetics Department

The mission of the Human Genetics Department is:

- Prevention of birth defects and genetic diseases.
- Early management of genetic diseases.
- Propagation of knowledge about genetic diseases among the public and post-graduate education.

The Department's activities include clinical genetics, cytogenetics, biochemical genetics, molecular genetics, craniofacial genetics and physical anthropology. The molecular genetic activities include molecular studies for prevalent genetic disorders for which DNA diagnosis is available, starting with prevalent disorders β -thalassemia, pseudohermaphroditism, phenylketonuria, fragile X-syndrome & Duchenne muscle dystrophy. Molecular studies for certain types of malignancy, particularly cancer of the bladder and leukemia are included. DNA finger printing for personal identification is also included. DNA diagnosis involves abnormal male sexual differentiation, phenylketonuria, hemoglobinophies, X-linked mental retardation, leukemia and cancer diagnosis and prognosis in Egyptians and DNA analysis of Ancient Egyptian specimens. The main ongoing projects are:

- Clinical, cytogenetics and biochemical studies of birth defects in Egyptians.
- DNA techniques in the diagnosis of prevalent genetic diseases in Egypt.
- Molecular defects in the human androgen receptor gene and their linkage to genetic markers for early diagnosis and carrier detection of the Androgen Insensitivity Syndrome.
- Oncogene activation in bilharzial bladder cancer in Egyptian patients.
- DNA polymorphism in the Egyptian population.

Genetics and Cytology Department

The ongoing research work of the Genetics and Cytology Department includes:

- Improvement of industrial microorganisms such as yeast and *Aspergillus sp.*
- Mutagenesis and protoplast fusion.
- Improvement of bio-pesticides.

Biochemistry Department

The ongoing research work of the Biochemistry Department includes bilharzia (*Schistosoma sp.*) control.

Microbiological Chemistry Department

The ongoing research work includes production of microbial useful compounds e.g. ethanol using agro-industry wastes and production of bio-pesticides using sugar-industry wastes.

Multipurpose Pilot Unit for Biotechnology

The Multipurpose Pilot Unit for Biotechnology is under construction.

Mubarak City for Scientific Research and Technological Applications

Mubarak City for Scientific Research and Technological Application contains two institutes, the Genetic Engineering and Biotechnology Research Institute (GEBRI) and the Informatics Research Institute (IRI). The two institutes were officially opened on 13 August 2000. The Genetic Engineering and Biotechnology Research Institute (GEBRI) conducts research in modern biotechnology and genetic engineering. The establishment of GEBRI had biotechnology transfer, educative, training and direct practical components. It was established as a centre of excellence in advanced biotechnology to introduce different valuable biotechnology products to the market through R & D and by technology transfer to produce commercial biotechnology products jointly with private companies.

Goals of GEBRI are:

- Improvement and development of expertise and knowledge in biotechnology and genetic engineering.

- Utilization of this expertise to offer services for Egyptians.
- Gaining financial returns to help institute to sustain its activity.
- Improvement of the image of scientific performance in Egypt to pave the way for cooperation between Egypt and industrial countries that have made significant achievements in modern biotechnology.

Major R & D areas of GEBRI:

- Health biotechnology.
- Environmental biotechnology, with a focus on bioremediation.
- Bioprocessing.
- Marine biotechnology.
- Agricultural biotechnology.
- GEBRI Departments:
 - Nucleic acid Research Department.
 - Protein Research Department.
 - Biomedical Research Department.
 - Environmental Research Department.
 - Industrial Biotechnology Development Department.

Theodore Bilharzi Research Institute

Biochemistry Department

The mission of the Biochemistry Department involves biochemistry (proteins and enzymes), molecular biology (recombinant DNA, RNA and protein), molecular diagnosis and vaccine development. The main ongoing research subjects and activities are:

- Using recombinant DNA techniques for the production of specific proteins which could be identified by the human system.
- Using specific cDNA probes for diagnosis of viruses.
- Using recent techniques in molecular biology to study the regulation of gene expression in pathophysiological states.
- Molecular diagnosis of hepatitis B and C viruses by PCR and in-situ hybridization, in serum and liver tissues.

- Molecular diagnosis of *Mycobacterium tuberculosis* in all fluids by PCR.
- Molecular diagnosis of genetic diseases by PCR.
- Training courses in the field of molecular biology techniques and their application.

Immunology Department

The mission of the Immunology Department is the production of monoclonal antibodies, immunology and molecular biology.

MINISTRY OF AGRICULTURE

The agricultural policy of Egypt aims mainly to achieve the maximum yield production with high standards of quality and safety in products. Such objectives would not be achieved without the great efforts of His Excellency, Professor Dr. Youssef Wally, Deputy Prime Minister and Minister of Agriculture and Land Reclamation, who has kindly encouraged introducing new and advanced technology in all the agricultural sectors.

Agriculture Research Centre (ARC)

Agriculture Genetic Engineering Research Institute (AGERI)

AGERI is one of the leading institutions in the field of agricultural genetic engineering in the regions of West Asia, North Africa and the Middle East.

The main ongoing research subjects are:

- Production of virus-free potato plants.
- The use of Restriction Fragment Length Polymorphism (RFLP) as molecular markers to increase plant breeding efficiencies.
- Studies on the genetic transfer of genes controlling growth maturity and quality.
- Gene cloning and production of transgenic plants resistant to pathogens.

Finger Printing Laboratory

The Finger Printing Laboratory is a specialized unit that was recently established in the Plant Pathology Research Institute at the Agriculture

Research Centre, to develop a fingerprinting documentation system for pathogenic microorganisms and certain plant cultivars (distinguished by high levels of resistance or susceptibility to the most economically harmful plant diseases). This lab offers services that cover a wide range of scientific applications in agricultural, clinical, medical and veterinary research.

Department of Microbiology, Water and Soil Institute

In the Water and Soil Institute of the Department of Microbiology, the main ongoing research work (using the conventional techniques) deals with nitrogen fixation, single cell protein and bio-gas production.

Field Crop Research Institute

The main responsibility of the Field Crop Research Institute is the selection and breeding of high production varieties of field crops resistant to pests and adaptable to unsuitable conditions in reclaimed lands.

Horticulture Research Institute

The main responsibility of the Horticulture Research Institute is horticulture and field production improvement. It works on designing breeding programs to produce resistant varieties and the establishment of gene banks.

Animal Reproduction Research Institute

The main responsibility of the Animal Reproduction Research Institute is improvement of the fertility and reproductive capacity of farm animals. The institute works with production of frozen semen from selected bulls used in artificial insemination, application of artificial insemination and embryo transfer.

Tissue Culture Laboratory (Development of Agriculture Systems Project)

The main ongoing research subjects of the Tissue Culture Laboratory are:

- The *in vitro* micro-propagation of banana.
- The *in vitro* micro-propagation of some ornamental plants.
- Production of virus-free potato plants.

Tissue Culture Unit of the Desert Research Centre

The main objectives of the Tissue Culture Unit of the Desert Research Centre are studies on the date palm and on salinity and drought stresses.

Veterinary Vaccine Research Institute

The Veterinary Vaccine Research Institute works on animal vaccine production by modern technologies.

OTHERS

WHO Collaborating Centre for Viral Diseases

The WHO Collaborating Centre for Viral Diseases is working in the fields of virus antigen, tissue culture and production of vaccines.

Naval American Middle East Research Unit (NAMERU)

The main ongoing research of the Naval American Middle East Research Unit is related to human health safety. For example, identification of specific proteins which can be detected by the human immune system against bilharzia (*Schistosoma sp.*) using DNA technology.

ACADEMIC ACTIVITIES OF THE UNIVERSITIES

There are 13 large Egyptian universities that support science faculties, 8 of which I have included in my paper. Each is comprised of departments covering most scientific fields, including medicine, pharmacology, veterinary medicine, engineering, agriculture and dentistry. Several research centers are found in Egyptian universities. In addition, cooperation between various university laboratories, research institutes and private industry is beginning to take shape.

Ain-Shams University

Microbiological Resources Centre, (MIRCEN)

The Microbiological Resources Centre at Ain-Shams University represents part of the international program for stimulating the conservation and utilization of microbial genetic resources for environmental management in developing countries.

Ain Shams Genetic Engineering and Biotechnology Center

The Ain Shams Genetic Engineering and Biotechnology Center consists of several laboratories at the Faculties of Agriculture, Medicine, and Science. The main activities include:

- The study of biomass, recycling and bioremediation.
- Establishment of plant gene banks.
- Research concerning bilharzial vaccine by recombinant DNA technology.
- Research concerning molecular probes for tumors.

Tissue Culture Laboratory, Faculty of Agriculture

The Tissue Culture Laboratory, Faculty of Agriculture, Ain Shams University is working on the *in vitro* micro-propagation of strawberry, asparagus and artichoke.

Department of Genetics, Faculty of Agriculture

The main ongoing research projects of the Department of Genetics, Faculty of Agriculture, Ain Shams University are searching for the mutagenic potentiality of pesticides used in Egypt on the cellular and subcellular levels and development of a genetic atlas for the main economic varieties of Egyptian crops using biochemical genetic fingerprints.

Genetic Diseases Centre

The Genetic Diseases Centre, Ain Shams University covers a number of activities in the health field, such as tissue culture, biochemical and biomedical genetics, and immuno-genetics.

Faculty of Science

The Faculty of Science, Ain Shams University is doing work on the development of bilharzial vaccine by recombinant DNA technology.

Al-Azhar University

Tissue Culture Laboratory, Faculty of Agriculture

The activities in the Tissue Culture Laboratory, Faculty of Agriculture Al-Azhar University include improvement of some field crops using tissue

culture techniques and *in vitro* micro-propagation of some ornamental plants through tissue culture techniques.

Alexandria University

Institute of Graduate Studies and Research

The Department of Biotechnology, Institute of Graduate Studies and Research, Alexandria University offers a degree in biotechnology and stresses studies on biodegradation of pollutants, including studies on using microorganisms for the purification of sewage water to be reused in irrigation.

American University in Cairo

Tissue Culture Unit, Desert Development Centre, Sadat City

The Tissue Culture Unit, Desert Development Centre, Sadat City is one of the projects running by the American University in Cairo. The main ongoing work is the mass production of plant windbreaks (*Casuarina sp.*).

Cairo University

Genetic Engineering Centre, Faculty of Agriculture

Current projects at the Genetic Engineering Centre, Faculty of Agriculture, Cairo University include tissue culture growth of native clover, and biotechnology, including gene cloning and plant transformation.

Animal Biotechnology Laboratory, Faculty of Agriculture

The Animal Biotechnology Laboratory, Faculty of Agriculture, Cairo University carries out research in tissue culture, immunology, genetics, endocrinology and immunogenetics—environment interaction. It also conducts research on genetic mapping of loci related to disease resistance.

Plant Department, Biotechnology Laboratory

The Plant Department Biotechnology Laboratory carries out research on salt-tolerant and drought-tolerant crops.

Biotechnology Centre, Faculty of Pharmacy

The main activities currently under investigation

at the Biotechnology Centre, Faculty of Pharmacy, Cairo University are related to industrial biotechnology, animal tissue culture and genetic engineering.

Mansoura University

Faculty of Medicine

The Faculty of Medicine at Mansoura University carries out research activities related to the detection of gene defects in thalassemias in Egyptians.

Menofia University

Tissue Culture and Genetic Engineering Center, Sadat City

The Tissue Culture and Genetic Engineering Center, Sadat City, operated by Menofia University, was established in collaboration with Darmstadt University (German aid) to work in the fields of protoplast fusion, gene transfer, monoclonal antibody production and pharmaceutical problems.

Suez Canal University

Plant Tissue Culture Laboratory, Faculty of Agriculture

The main ongoing research subjects of the Plant Tissue Culture Laboratory, Faculty of Agriculture, Suez Canal University are *in vitro* micro-propagation of virus-free strawberry plants potato improvement through *in vitro* techniques.

Faculty of Science

The Faculty of Science, Suez Canal University is conducting research using some plant species for the biodegradation of water pollutants.

ACTIVITIES OF INDUSTRIAL UNITS

Besides the numerous research and development laboratories and centers engaged in biotechnology development, there are a number of public and private industrial units which apply conventional and advanced biotechnology in the production process.

During the past 40 years, some examples of these applications have included bigots production, sewage and waste water treatments, high fructose syrup production from maize starch, breeding of new plant and animal cultivators, biological

fertilization using blue green algae and nitrogen fixing microorganisms, artificial insemination in animals, and artificial hatching of fish and intensive fish culturing. These applications have also included the production of ethanol, acetic acid, ethyl acetate, butylacetate, acetone and butanol by fermentation processes as well as production of compressed and active yeast, mainly from molasses.

The production of chemicals, such as citric acid from *Aspergillus niger*, and lactic acid from *Lactobacillus spp.*, has been recently started. The basic antibiotics, (penicillin and tetracycline) and the enzymes amylase and proteinases are also being produced. Brewing and wine-making are growing industries in Egypt using different microorganisms and yeast in processing and will provide a suitable base for biotechnology development.

The Egyptian Organization for Biological Products and Vaccines (EOBPV) as well as the Veterinary Vaccines and Inoculum Institute produce a range of human and livestock vaccines including TAB (typhoid/paratyphoid), cholera, B.C.B., diphtheria, tetanus, pertussis, Riff Valley fever and rabies viruses.

THE AGERI EXPERIENCE: BIOTECHNOLOGY FROM LABORATORY TO MARKET

The Egyptian agricultural sector is in the process of major change. The Egyptian government is moving towards privatization. Transfer of technology to the private sector occurred, in the case of *in vitro* micro-propagation of virus-free potato technology by AGERI, in 1993. This shows the capacity and interest of the private sector to adopt new technology. This aspect of technology transfer is expected to grow dramatically in the current phase as the research program of AGERI becomes more product-oriented.

The relationship between AGERI, an Egyptian public sector institution, and Pioneer, a US private company, was forged through a relationship that involved common business interests. Co-development of technology as opposed to technology transfer is especially important. A public-sector institution is able to bring a significant contribution to the table. AGERI has isolated a number of strains of *Bacillus thuringiensis* that have pesticidal activity of interests to a private-sector company. AGERI has also a state-of-the-art

biosafety facility and a cadre of trained scientists. Finally, AGERI could provide access to the local Egyptian market and the broader Middle East market, both of which are sufficiently developed to be attractive. In turn, Pioneer came to the table with technology as well as with marketing, regulatory and legal expertise of value to AGERI.

A second model of moving research into commercial application is elaborated through the successful interaction between scientists at AGERI and the University of Wyoming involving collaborative research studies for the past six years on *Bacillus thuringiensis* (Bt). The research efforts led to the development of a biological pesticide based on a highly potent strain of Bt isolated in the Nile Delta. This strain is extremely effective against a broad range of insects. An additional significant feature of this strain is its capacity to kill nematodes. AGERI has managed to successfully manufacture its first bio-pesticide (AGERIN) based on the insecticidal bacterium Bt.

In order to fulfill its commitment to bring research results into application and large scale commercial distribution to the target end-users, namely the farmers, AGERI established a commercial business entity under the name BIOGRO. This company will be responsible for the commercialization of research results conducted in AGERI and will be in a position to sell products of AGERI. This is essential to guarantee that sales revenue will be pumped back to the institute to support the continuation of its activities.

As one of the leading institutions in the field of agricultural genetic engineering in the regions of West Asia, North Africa and the Middle East, AGERI is planning to share its know-how and experience with the Inter-Islamic Network (INOGE) countries within the framework of Technical Cooperation among Developing Countries (TCDC). This will be achieved through the organization of specialized workshops, seminars and internships. Moreover, the institute can provide professional consultation in the field of molecular biology and agricultural genetic engineering.

PLANT BIOTECHNOLOGY IN PRIVATE COMPANIES

Some private companies in Egypt have been using plant tissue culture techniques especially for *in vitro* micro-propagation of some plants such as

banana, potato and ornamental plants. Among these companies are BECO, DANTON and El-Shiaty.

DNA BIOTECHNOLOGY IN PRIVATE CLINICAL LABORATORIES

Many private clinical laboratories are using DNA techniques in diagnosis of prevalent genetic diseases in Egypt. This includes molecular diagnosis of hepatitis B and C viruses by PCR.

Conclusion

As a result of the activities delineated above, many achievements have been reached as a result of the great attention that has been paid to biotechnology, covering training studies, training courses, scientific conferences, scientific cooperation, intellectual property rights (IPR), scholarships and the funding of research projects.

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