National State-of-the-Art Report on Biotechnology

1. Name of the country

PAKISTAN

2. Name, Address and Contact details including telephone, fax, email, etc. of the focal Ministry/Institution on Biotechnology

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3. Name, Address and major activities of the key R&D organizations / academic institutions involved in biotechnology activities (Government, NGOs and private organizations)

A. Center of Excellence in Molecular Biology, University of the Punjab, Lahore.

Objectives and Functions of the Center

- Teaching and training to generate a cadre of manpower specifically trained in molecular biology and recombinant DNA technology.
- To undertake goal oriented molecular biological research on specific problems related to economic needs of the country for agriculture, health & medicine, industry, energy and environment sectors.
- To create a repository of DNA modifying enzymes, DNA cloning vectors, novel bacterial strains and other such molecular tools for ready availability and use by various
- Research groups at this Centre and other DNA research laboratories in Pakistan.
- To organize National and International seminars and conferences for detailed' discussions on scientific and technological developments, which will lead to new ideas and innovative applications of knowledge in gene cloning and recombinant DNA Technology.

Activities

- Diagnosis of infectious diseases
- Diagnosis of genetic diseases
- Stem cell research
- Teaching and training
- Basic Research
- Criminal identification
- Transgenic plant biotechnology

- Plant fungal interaction
- Production of DNA enzymes
- Environmental Biotechnology

Achievements

- Established PCR based clinical tests at commercial level for diagnosis of hepatitis (B. C & A) & tuberculosis.
- Provided the general public reliable, accurate, rapid and more economical diagnostic service on economical rates (20%-30% less than market).
- CAMB has gained nation wide reputation and is receiving samples from allover Pakistan.
- Optimized the in-vitro growth conditions for stem cell proliferation from bone marrow.
- Characterized stem cells with the help of cell surface markers.
- Produced mice myocardial infarction models.
- Designed and synthesized primers for the molecular studies of interferon gene.
- Cloning of human interferon gene was successfully achieved.
- **Research Outcomes -Patents -Commercialization**
    - Two patents (Patent # 137087) and (Patent # 137121) were submitted for processing of Biopesticide formulation.
    - Procedures for prenatal diagnosis of β-thalassemia, DNA typing for criminal investigation and parenthood identification, and PCR based diagnosis of infectious diseases (hepatitis B&C and tuberculosis) have been commercialized.
    - Taq polymerase enzyme and DNA markers are available on a semi commercial scale .while two enzymes are being marketed by a US Company.

B. Agricultural Biotechnology Research Institute, AARI, Faisalabad.

FUNCTIONS:

- Use of biotechnological tools for the improvement of major crops.
- Research Assistance to other AARI institutes through:
    - Micro propagation
    - Somaclonal Variation
    - Doubled Haploid Breeding
    - Genetic Diversity studies
    - Molecular Breeding
    - Mutation Breeding

- Human Resource Development

RESEARCH ACTIVITIES:

Agricultural Biotechnology Research Institute is engaged in research work for the improvement of major crops using latest biotechnological means and collaborating with other crop institutes in this regard. Following are the research areas on which research experiments are in progress:

- Genetic diversity studies in following crops through molecular markers to ascertain genetic distances and similarities for the guidance of breeders:
    - Wheat
    - Rice
    - Cotton
    - Sugarcane
    - Brassica
    - Olive
    - Groundnut
- DNA marker assisted breeding in wheat and rice for the development of disease resistant varieties.
- Development of transgenic Brassica with low erucic acid through RNA interference technique.
- Oil quality improvement in B. Juncea through mutation approaches.
- Molecular tagging of CLCuD resistance gene in cotton (G. arboreum).
- Rapid varietal development in wheat through Doubled Haploid breeding
- Exploitation of somaclonal variation in wheat and sugarcane to enhance and create variability for the selection of genotypes with desirable traits.
- Micropropagation in following crops/plants for the rapid production of disease free seed:
    - Sugarcane
    - Potato
    - Banana

ACHIEVEMENTS:

1. One high yielding and rust resistant wheat variety Ufaq-2002 was developed through somaclonal variation and approved for general cultivation in the irrigated areas of Punjab province.

2. Sugarcane variety HSF-242 was made red rot resistant through somaclonal variation in collaboration with Sugarcane Research Institute and was approved for general cultivation during 2007. Developed red rot resistant somaclones from their susceptible parents S97US297 and SPSG-394. Also developed red rot, rust and pokha boeing resistant somaclones from susceptible parent BF-162.

3. About 0.1 million micro-propagated plantlets and 0.75 million kg disease free seed of sugarcane was produced and disseminated to the farmers.

4. Six hundred and fifty doubled haploid plants of wheat were produced and handed over to Wheat Research Institute and Barani Agriculture Research Institute for rapid varietal evolution.

5. Molecular characterization of rice (71 genotypes), sugarcane (80 genotypes) and wheat (60 genotypes) germplasm was accomplished using RAPD (Random Amplified Polymorphic DNA) and SSR (Simple Sequence Repeats) techniques.

6. DNA marker assisted breeding for rusts in wheat has been initiated using published molecular markers and identification of DNA markers for yellow and brown rusts is underway.

C. National Institute for Biotechnology and Genetic Engineering, Faisalabad.

The National Institute for Biotechnology & Genetic Engineering (NIBGE), Faisalabad, during short span of time, it has established itself as Centre of Excellence in Biotechnology by upgrading its infra-structure and improving the quality of scientific manpower. As first Director General, it is always heartening to see this Institute blossom.

One of the objectives while establishing NIBGE was to develop 'receiving units' for the new emerging technologies. For this purpose, NIBGE has developed infrastructure which is at par with international standards and has thus been able to establish several linkages with various biotechnology laboratories in advanced countries.

NIBGE has become internationally a lead centre for research on cotton leaf curl virus by deciphering the virus genetic code and documenting the genetic diversity existing in the field. A useful input from University of Arizona, Tuscon; John Imn Centre, Norwich,

UK; Imperial College and Queen Mary College London resulted in accumulation of useful data, which is now being utilized for developing transgenic cotton resistant to CLCuV. Similarly establishmentk of a Plant Genomic Laboratory in collaboration with PARC (Pakistan Agricultural Research Council) is a step in right direction. The Institute has also excelled in the area of biofertilizers with support from IAEA and more recently from Islamic Development Bank through which Biofertilizer Resource Centre (BIRCEN) has been established at NIBGE. Commercialization of biofertilizers under the trade name of BioPower is greatly helping in development of sustainable agriculture.

The Institute has been a pioneer in establishing PCR based diagnostic techniques for infectious diseases which are now routinely done in many hospitals. Our contribution regarding genotyping of Hepatitis-C virus in our local population has also been greatly appreciated. NIBGE is soon going to have state-of-the-art equipment (CV Chromoscan) for doing human chromosomal analysis, karyotyping, molecular diagnosis for genetic disorders and cancers and comparative genomic based hybridization.

NIBGE by all means, has emerged as a focal point for all national and international activities related to biotechnology in the country. Human resource development is the cornerstone for development in this area. NIBGE is thus contributing effectively by conducting M.Phil Biotechnology programme in collaboration with the Quaid-e-Azam University, Islamabad. This is now being extended to Ph.D. programme. NIBGE has also taken a lead role in the finalization of Biosafety Guidelines for Genetically Modified Organism (GMO). For this purpose a series of training courses for capacity building in Environmental Impact Assessment will be held during the current year.

Bioinformatics is fast developing as a discipline and NIBGE has already initiated a Bioinformatics Cell, with the help of computer specialists in simulation and modeling. Other organizations of PAEC are instrumental in providing help and assistance in this regard.

In the present scenario of WTO and various IPR constraints, development and commercialization of biotechnology has become complex and needs special skills. Through the commercial biotech company, PIBS, established by NIBGE, efforts will be made to resolve such issues and to enter into joint venture agreements with international private sector biotech companies which will eventually help in the transfer of technology.

PAEC has always been on the forefront for acquiring new and emerging technologies. Hence, PAEC took the initiative way back in 1987 for establishing National Institute for Biotechnology & Genetic Engineering which was formally inaugurated in January 1994 by the President of Pakistan. PAEC has always been generously supporting activities in biosciences involving use of nuclear techniques in agriculture and medicine. PAEC, in addition to NIBGE, runs three Agriculture Research Institutes namely NIAB, Faisalabad; NIA, Tandojam and NIFA, Peshawar. In addition, PAEC runs thirteen Nuclear Medical Centres all over Pakistan. PAEC intends to continue supporting R&D activities in all related areas of life sciences.

Research Activities:

- Genomic studies in different crops
- Transformation in cotton for insect resistance
- Transformation in cotton for virus resistance
-

D. Institute for Biotechnology and Genetic Engineering, University of Sindh, Jamshoro

The aim objectives of the Institute are Teaching and Research

- The institute is engaged to provide quality education and research environment for students to uplift economy of Pakistan by improving education, upgrading healthcare, industry and agriculture according to global development.

- To train needed scholars and researchers in the field of Biotechnology and Genetics.

- Presently Institute is engaged in developing modern biotechniques based on high academic level research associated to specialized human resources training. Students are encouraged to explore not only new conceptional connections but to engage in active group learning experiences and to prepare themselves as future research leaders in life sciences.

- To promote the field of Biotechnology and Genetics in the country, through organizing symposium, training courses, correspondence, publication of scientific research journal, articles and books.

E. Institute for Biotechnology and Genetic Engineering, Peshawar

Biotechnology has emerged as a revolutionary development, which has the potential to galvanize and broaden the base of industrial structures in developing countries and to discover new directions in agriculture, environment, health, industry and energy. There are clear indications that this new technology will have a significant role in the future economic growth of developing countries. Responding to the challenges, the University decided to integrate biotechnology into its education and research system through establishment of Institute of Biotechnology and Genetic Engineering, (IBGE). The IBGE is a teaching and research institution engaged in training and research in the field of Biotechnology and Genetic Engineering, by focusing both education and research on solving the agricultural problems of NWFP in particular and Pakistan in general. It is envisaged that the Institute's laboratories will provide a

unique place in the country where original basic and applied biotechnology research of international standard will be conducted. Currently the Department is running the following Projects:

- Genetic Improvement of Brassica Oilseed (Aphid Resistance) by Integrated Use of Conventional & Molecular Biological Approaches (ALP Project).
- Genetic Improvement of Brassica Oilseed Yield Through Integrative Use of Conventional and Molecular Biological Approaches.
- In Vitro Development of Stress Tolerant Plants in Wheat.

F. National Institute for Genomics and Advanced Biotechnology (NIGAB)

Genomics and proteomics are two very important expanding fields expected to lead to the development of additional gene-based drugs, new generation of vaccines, diagnostic tests for the detection of genetic conditions, providing means of identifying and characterizing disease specific proteins as well as proteomics that play important role in growth, reproduction and metabolism of animals, microbes and plants.

The ultimate goal of initiating genomic studies is to understand the structure and function of every gene in an organism. With the intent of exploring this knowledge for the betterment of society, efforts will be made to focus on plant species, food, animal species and microbes important to agriculture and live stock.

NIGAB will facilitate in discovering new genes, functions of the genes, structural and genomic organization of the genes, DNA markers for different traits of interest etc which will play a pivotal role in developing new crop varieties and animal breeds, development of new drugs, generation of new knowledge and development of human resource. This increased emphasis on the genome will radically change fundamental agriculture & livestock research along with the environment in the country.

G. Centre of Agricultural Biochemistry and Biotechnology (CABB), University of Agriculture, Faisalabad.

Objectives:

- To upgrade teaching and research by integrating biotechnology into existing traditional systems of agriculture
- To offer degree courses, in service trainings and short courses in agricultural biotechnology
- To collaborate in academic/research pursuits with other departments in the University.

- To collaborate research among various national and international research institutes
- Human resource development in Agricultural Biotechnology
- Conservation, molecular characterization and documentation of crop germplasm, and MAS to assist plant breeders for the development of modern crop cultivars
- Use of molecular approaches and in vitro techniques in plant propagation, crop improvement and plant disease management
- Introduction of genetic engineering of crops as a regular feature for crop improvement research

Research Projects:

- Molecular Characterization of Available Germplasm of Wheat in Pakistan (Funded by ALP PARC (Islamabad)
- DNA marker studies of Fusarium wilt in Chick pea (Funded by ALP PARC (Islamabad)
- Strengthening and up-gradation of CABB (Submitted to HEC)
- Up-gradation of laboratory and library facilities in CABB (Submitted to HEC)
- Genetic Diversity studies in Tomato using Molecular Markers
- Gene functional analysis through transposon induced mutations in rice
- Disease Free Seed Production of Sugarcane Through Tissue Culture

Expected Outputs

- Development of well trained manpower to meet the future demand of agricultural research
- Molecular characterization of plant genetic resources to support IPRs and PBRs
- Marker Assisted Breeding to support development of modern cultivars and hybrids
- Development of Transgenic Cultivars and hybrids
- Testing of transgencity and Biosafety of transgenics

H. Department of Biotechnology, University of Karachi

Objective

Scope of Biotechnology Integration of biological sciences with other disciplines particularly chemistry and process engineering has resulted in the emergence of novel concepts and technologies with applications in and consequences for agriculture, medicine, health care, industry, environmental pollution cleaning of oil spills in the seas, development of safe and environment-friendly bio insecticides, energy generation and several other sectors of activity.

The common denominator which links these areas together are cells and products derived from them.

The use of bio-cellular materials in conjunction with chemical and process engineering have ushered in a new kind of revolution wherein it is possible to create transgenic animals plants and microbes which otherwise could not have come into being in the foreseeable future.

For that matter without Biotechnology it would not be possible to create bio-degradable plastics or try to replace defective genes with good ones in patients afflicted with potentially or certainly fatal hereditary diseases.

The pivotal role in the unfolding biotechnological revolution is of the recombinant DNA technology popularly known as Genetic Engineering. Major Problems facing Pakistan These are:

1. Providing adequate food, both from the agricultural and animal husbandry sectors, for a fast-growing population.
2. Low productivity.
3. Salinity.
4. Water-logging.
5. Water shortage.
6. Use of pesticides, which have injurious effect on plants, soil and ecology.
7. Shortage of energy, and unwise use of our limited gas resources as fuel.
8. Pollution (air, water and noise).
9. Use of industrial processes which are either capital-intensive or high-energy consuming or both, and in which our national resources are already over-strained.

Biotechnology offers processes which are less expensive, less injurious and yield speedier results. But the question of use of appropriate technology demands not only proper study and selection of the processes evolved by the developed countries but also their adaptation to suit our needs.

In addition we have to build up the requisite infrastructure and develop our human resources to create a highly trained cadre of scientists, research scholars and technicians.

While Pakistan has a couple of institutes providing facilities for postgraduate research and training, there is no department or institute which provides for organized teaching in biotechnology at all levels i.e. undergraduate, graduate and post-graduate. The newly established department will fill this gap.

The graduating students will be able to play a significant role in the national development through their services rendered to educational institutions, R&D organizations and existing and future industrial setups.

Alternatively they will be able to effectively compete for admission in foreign institutions for doctoral and post-doctoral training or for jobs in biotechnology companies.

4. Present status of different areas of biotechnology

4.1 Plant biotechnology

The green revolution brought prosperity and food security but is not sufficient to ensure future food requirement for a country like Pakistan where population growth rate is very high. With limited land and water resources the only option left is to enhance food and fiber production by input of technology. Biotechnology offer unlimited genetic resources because of the ability to utilize diverse genetic resources for plant improvement that can enhance both the quantity and quality of food and fiber demands of the country. An emerging area of research is the application of plants in energy sector as well as healthcare of population.

Activities in Agricultural Biotechnology are aimed at use of modern molecular methods to understand problems that limit crop productivity, isolate relevant gene(s) that can confer novel agronomic traits, transform those genes in crop plants and characterize engineered plants under glasshouse and field conditions. Development and utilization of DNA markers for marker-assisted selection of desirable plants is another approach that has been used to develop superior plant varieties. The program is ultimately aimed at characterization and enhancement of germplasm resources in the country which is vital for maintaining competitive edge of the country in agriculture sector and safeguard National interest in WTO regime. Another research aspect is the establishment and utilization of Genomics and Proteomics tools for understanding of key pathways important for crop productivity. These activities are expected to enhance crop productivity, reduce cost of production and reduce losses by disease and insects.

The work on Molecular Virology and RNA Silencing involve understanding virus disease complexes that are major limiting factor to crop productivity. Understanding of complexity and evolution of virus-disease complexes and critical analysis of viral genes that overcome host defenses are the priority. This is the most active work on emerging viral diseases in the developing world. The technologies for control of these complexes through genetic engineering and novel application of gene silencing technologies are also being developed.

The work on Plant Molecular Biology and Transformation is aimed at isolation of novel genes and their cloning in plant expression vectors with necessary modifications to optimize their expression in plants. Specialization in transformation of crop plants including cotton, tobacco, sugarcane and potato has been developed. Important traits being engineered in cotton are insect resistance, virus resistance, abiotic stress tolerance and fiber improvement. The gene constructs are also being developed for novel agronomic traits in crop plants.

In Plant Genome Resource area, several cDNA libraries have been developed that are being used to identify fiber and disease related genes in cotton. The Genome mapping lab is working on rice as a model system.

The Plant Genomics and Molecular Breeding work include DNA fingerprinting technology, molecular markers, cotton genomics and use of molecular markers in crop breeding.

The Proteomics and Stress research work include use of genomic approaches to identify stress related proteins. Work has been initiated on improvement of wheat through genetic engineering.

The insect molecular biology works on molecular characterization of important insects and understanding of novel technologies developed for control of insects.

Work on development of transgenic Brassica with low erucic acid through agrobacterium, mediated transformation is in progress.

Rapid varietal development in wheat through Doubled Haploid breeding is aroutine process.

Exploitation of somaclonal variation in wheat and sugarcane is being carried out to enhance and create variability for the selection of genotypes with desirable traits.

Micropropagation in following crops/plants for the rapid production of disease free seed:

- Sugarcane
- Potato
- Banana

4.2 Animal biotechnology

The discovery that DNA, the carrier of the genetic code for any form of life can be transferred into any other form of life opens the door to a multitude of possibilities for genetically modified plants, animals and microbes not found on earth until now. A career that is impacted by molecular biology and biotechnology is not just a job. Following are the major activities in the field of animal biotechnology.

- Characterization and Improvement in live stock through DNA finger printing of all major breeds.
- Vaccine production for live stock and poultry.

- Molecular diagnostics and differentiation for major livestock diseases.

4.3 Health and Industrial biotechnology

Biotechnology is at the vanguard of new methods for the efficient and clean production of biological materials and chemicals. These environmentally friendly processes utilize the power of biology to make antibiotics, enzymes, proteins and chemicals for commercial uses. Economical production using biological systems is not always simple and has to be performed safely and reliably. The aim of our research is to investigate and develop innovative systems, so as to intensify and simplify the control of bioprocesses ensuring safe, reliable and cost-effective production and recovery of biologically derived material. Because bioprocesses use living material, they offer several advantages over conventional chemical methods of production: they usually require lower temperature, pressure, and pH; they can use renewable resources as raw materials; and greater quantities can be produced with less energy consumption.

The many potential uses of biotechnology are developed through laboratory procedures that generally produce only small amounts of useful substances. As advances in bioprocess technology, particularly separation and purification techniques, are made, commercial firms will be able to economically produce these substances in large amounts, and thus make them available for use in medical research, food processing, agriculture, pharmaceutical development, waste management, and numerous other fields of science and industry. Therefore, we can rightfully use this notion that biotechnology has been transformed from a laboratory science into an industry. The current research focus of Industrial Biotechnology division encompasses following areas:

- Bioresource Development for Industry
- Industrial Enzymes, Biochemicals and Biofuels
- Bioprocessing of Ores and Fossil Fuels
- Nanobiotechnology

4.4 Health biotechnology

Overall Objectives

To enhance the health and high quality of every Pakistani individual by providing diagnostic service, teaching and conducting research in laboratory medicine using cutting edge biotechnological approach.

Specific Objectives

- Molecular epidemiology of viral hepatitis, typhoid, enterobacter pathogens and tuberculosis
- Identification, characterization of biologically immunogenic protein antigens for development of modern vaccine and diagnostic kits
- Finding protein-based biomarkers for disease diagnosis.
- Linkage analysis of monogenic genetic disorders
- PCR-DNA based molecular diagnostic services (commercial aspect)

Historical Prospective

The health related work was initiated in PAEC for NIBGE at Biomedical Division at INMOL, Lahore soon after the approval of PC1 in 1988. Later, with the establishment of NIBGE at NIAB Campus, Faisalabad in 1991, the Health related work was initiated in Basic Biology Division. With the passage of time and in the interest of NIBGE, the name of this division was changed to Basic Biology and Molecular Medicine Division and finally to Health Biotechnology Division (HBD). A separate new block of HBD was established in 1999.

Facilities Available for Research and Diagnostics

HBD consists of a two-storied building for biomedical research and molecular diagnostics at NIBGE premises. This building has a separate PCR/DNA diagnostic section; cytogenetics; human genetics laboratory; human tissue culture laboratory; bacterial culture laboratory; typhoid and enterobacter research laboratory; DNA cloning/analysis laboratory; metabolomics laboratory; DNA/ protein analysis laboratory and a walk-in cold room.

HBD at NIBGE has research and diagnostic facilities to carry out research in areas of infectious diseases (HBV/ HCV, tuberculosis, enteropathogens), genetic diseases (β-thalassemia, leukemia and other monogenic disorders); modern vaccines (conjugate vaccines, recombinant and therapeutic HBV vaccines); biologicals (Streptokinase, tissue plasminogen activator and growth hormone) and diagnostic kits development (PCR diagnostics/ Immuno-chromatographic strips). This division is equipped with DNA sequencer; conventional PCR; real time PCR; gradient PCR; high speed refrigerated centrifuge; microfuges; incubators; shaking water baths; thermal block; freezers; refrigerators; cold cabinets; gel documentation systems; refrigerated shaker; CV chromoscan work station , safety cabinet (class II), fume hood and other routine instruments in molecular / biochemistry laboratory. The laboratories in HBD are fully equipped with trained scientists and experts in the areas listed in Annexure V.

Focus of Research and Diagnostics

HBD at NIBGE focuses its efforts on the early detection of infectious and genetic diseases prevalent in Pakistan. The division forges tools that are preferably applicable where sophisticated technology support is lacking, and are for the benefit of people with limited means. Research aims at the application of these tools for diagnosis of diseases in

clinical setting and for the epidemiological investigations. In the past ten years, this division has made good national and international collaborations with R&D institutions, pharmaceutical industries in its efforts to develop and evaluate methods for the detection of infectious and genetic diseases and production of recombinant therapeutic agents and vaccines.

Molecular Diagnostics

The first PCR-based diagnostic test was made available for public in 1995 after research and validation on Pakistani population and comparing results with conventional techniques. A number of seminars were delivered to the medical community to introduce the molecular tests for early diagnosis of diseases prevalent in Pakistan. A hard, concerted effort was made by the scientist working at HBD and the PAEC authorities to convince the medical community to consider and apply the new molecular tests and approaches as a useful tool for better diagnosis, prognosis and treatment of patients. The scientists working in this of division are providing diagnostic services to the patients and general public since 1995. The tests being performed in this division are as below:

- DNA/ PCR based test for the detection of tuberculosis, hepatitis B,hepatitis C, typhoid, bcr-abl translocation, detection of mutaions in β-thalassemia and male infertility in clinical samples.
- Detection of chromosamal abnormalities by karyotyping.

In-house PCR based tests need strict quality assurance and quality control measures to provide accurate and specific results. Health biotechnology team at NIBGE is an active member of the Regional Programme of IAEA, Vienna Austria for "Molecular Diagnosis of Infectious Diseases". The validation of In-house PCR test was conducted in collaboration with IAEA associated laboratories. Based on the expertise developed by scientists at HBD, we have developed NIBGE-One Step HBV-DNA PCR Kit for the detection of hepatitis B virus infection in clinical samples (see annexure VI). After accessing the capabilities of HBD scientists and laboratory environment in In-house PCR diagnostics, IAEA nominated the scientists of HBD as consultants and expert in this area. In addition to this, IAEA has now started sending persons from other countries to have training in molecular diagnostics at HBD, NIBGE.

4.5 Others

Environmental Biotechnology

Main aim of Environmental Biotechnology Division is development, use and regulation of biological systems for monitoring & remediation of contaminated environments (land, air, water) and pollution control. Other important research areas are genotoxicity testing and molecular detection of animal pathogens and provision of related training, services & facilities. Presently, following are mainly on going research and development activities at Environmental Biotechnology Division of NIBGE:

- Wastewater Treatment
- Bioremediation and Biodegradation
- Environment Toxicology and Mole
- Environment Testing Services

5. Government policy/legislation regarding application of biotechnology in national development

6. Priority areas for cooperation

- Agricultural biotechnology
- Health biotechnology

7. Areas of expertise available for cooperation

- Agricultural biotechnology
- Health biotechnology
- Industrial biotechnology
- Environmental biotechnology

8. Recent Biotechnology products/processes developed/ready for transfer

- Two patents (Patent # 137087) and (Patent # 137121) were submitted for processing of Biopesticide formulation.
- Procedures for prenatal diagnosis of β-thalassemia, DNA typing for criminal investigation and parenthood identification, and PCR based diagnosis of infectious diseases (hepatitis B&C and tuberculosis) have been commercialized.
- Taq polymerase enzyme and DNA markers are available on a semi commercial scale .while two enzymes are being marketed by a US Company.

9. Issues and challenges

- Bio-safety rules and regulations
- Trainings in nano-biotechnology
- Application of biotechnology in the field