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REVIEW PAPER

Biotechnology in India: Current Scene

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ABSTRACT

Realising the immense potential of biotechnology in the fields of agricultural production and health care, especially in developing countries, India has been devoting special attention over the past two decades to biotechnology and its applications. Necessary infrastructure has been built-up, the human resources and technical expertise built-up, and fruitful interactions between academic institutions and industries supported. The Department of Biotechnology, Govt of India has been playing a major role in this endeavour. Special efforts are being made to ensure practical applications of laboratory research. Salient achievements in the areas of agriculture (including tissue culture, transgenics, sericulture, animal, marine and microbial biotechnology, biofertilisers, bio-control agents, bio-prospecting, conservation of biodiversity and environment) and health care (including genetic counselling, DNA fingerprinting, preservation and propagation of human cell lines, medicinal biotechnology with special reference to indigenous medicinal plants, and immunodiagnostics for human beings and animals) are reviewed.

Keywords: Biotechnology, health care, transgenics, tissue culture, seriobiotechnology, animal biotechnology, bio-prospecting, marine biotechnology, biodiversity conservation, medicinal biotechnology, immunomodulators

1. INTRODUCTION

Realising the potential of biotechnology in our country's context, mainly in the fields of agricultural production and health care, India has, over the past two decades, been devoting special attention to the development of this technology and its manifold applications. Biotechnology has been identified as a thrust area in the past two Five-Year Plans of India.

For nearly five decades, Indian scientists have been deeply involved in research on basic aspects of biotechnology. Prof G.N. Ramachandran, FRS, was an outstanding authority in the field, who not only unravelled the structure of collagen, but also did fundamental work on biomolecular structure and function. Many of his co-workers are continuing the work in this exciting area. Dr A.R. Goipal-Ayengar was an internationally known geneticist who established an advanced school of research at the Bhabha Atomic Research Centre, Mumbai. The Tata Institute of Fundamental Research has a flourishing department doing outstanding research in the frontier areas of this field. Several research institutions and universities are carrying out excellent work in this area.

The scientific manpower that our country has built-up in the post-independence era is the most valuable input for a successful programme in

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biotechnology. This talent needs to be harnessed and oriented towards well-defined goals. In the larger context of our country's social and economic milieu, it is essential, apart from harnessing our R&D talent, to create the environment for a synergistic interaction among the scientists, technologists, entrepreneurs and the business community, and also to ensure that the fruits of the laboratory research reach the users in terms of better health care delivery and improved goods production. A brief account of the current status of biotechnology in our country is presented.

2. DEPARTMENT OF BIOTECHNOLOGY

The Department of Biotechnology (DBT) was set up under the Ministry of Science and Technology, in 1985. The present budget for the Department is around Rs 150 cr. The country has built-up biotechnology expertise in more than 25 institutions, including universities. Department of Biotechnology interacts with 5000 scientists from universities and academic institutions every year. There is collaboration with state governments (particularly through state S&T councils) for developments of biotechnology application projects, demonstration of proven technologies, and training. There have been 5000 publications, 4000 post-doctorals, 24 technology transfers to industries, and 41 patents (including 6 in USA). Focus has been on improving crop architecture, soil fertility, generating micropropagation protocols for economically important trees, developing vaccines and diagnostics, and new drugs, such as immunomodulators, specially from plant resources. A National Biosciences Development Board (NBDB) is being established at New Delhi[1].

2.1 Institutions Involved in Biotechnology Activities[1]

A list of institutions with infrastructural and advanced facilities established to-date is given below:

- National Institute of Immunology (NII), New Delhi (autonomous institution under DBT)
- National Centre for Cell Sciences (NCCS), Pune (autonomous institution under DBT)
- Centre for DNA Fingerprinting and Diagnostics (CDFD), Hyderabad (autonomous institution under DBT)
- National Brain Research Centre (NBRC), New Delhi (autonomous institution under DBT)
- National Centre for Plant Genomic Research (NCPGR), Jawaharlal Nehru University, New Delhi (autonomous institution under DBT)
- Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram, Kerala
- International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi
- National Virus Testing and Quality Control Facility (for Tissue Culture Raised Plants)
- Centre for Plant Molecular Biology (CPMB) (seven)
- Biotechnology Applications Centre, Madhya Pradesh
- Biotechnology Applications Centre, West Bengal
- Biomedical Engineering Research and Process Development Centre at the Institute of Microbial Technology (IMTECH), Chandigarh (for testing and standardising high value metabolites in large bio-reactors for commercial feasibility studies)
- Centre for Genetic Engineering and Strain Manipulation, Madurai Kamaraj University, Madurai (working on streptomycin group of antibiotics)
- National Facility for Microbial Type Culture Collection (MTCC) at the Institute of Microbial Technology, Chandigarh (conserving 10,000 species of industrial microbes)
- National Facility for Blue-Green Algae (BGA) Collection at the Indian Agricultural Research Institute (IARI), New Delhi (having 750 varieties of BGA)
- National Facility for Marine Cynobacteria at the Bharatridasan University, Tiruchirappalli (having 300 strains selected from Indian sea shores)

- National Facility for Plant Tissue Culture Repository at the National Centre for Plant Genomic Research (NCPGR), Jawaharlal Nehru University, New Delhi (having 850 *in. vitro* conserved crop species)
- Tissue Culture Pilot Plant and Micropropagation Technology Park at the National Chemical Laboratory (NCL), Pune
- Tissue Culture Pilot Plant and Micropropagation Park at the Tata Energy Research Institute (TERI), New Delhi
- Repository on Medicinal and Aromatic Plant Materials at the Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow
- Repository on Cryopreservation of Blood Cells at the Indian Institute of Haematology
- Repository on Filaria and Reagents at the Mahatma Gandhi Institute of Medical Sciences (MGIMS), Sewagram, Wardha
- Animal House Facilities at the Central Drug Research Institute (CDRI), Lucknow (having 80,000 animals)
- Animal House Facilities at the National Centre for Laboratory Animal Sciences (NCLAS) at the National Institute of Nutrition, Hyderabad (having 55,000 animals)

Six national facilities at the centres listed below are concerned with interactive graphics-based molecular modelling (including gene scan software package):

- Indian Institute of Science, Bangalore
- Madurai Kamaraj University, Madurai
- Centre for Cellular and Molecular Biology (CCMB), Hyderabad
- University of Poona, Pune
- Bose Institute, Kolkata
- Jawaharlal Nehru University, New Delhi

Four national gene banks have been established at the following centres:

- Tropical Botanical Garden and Research Institute, Thiruvananthapuram
- National Bureau of Plant Genetic Resources, New Delhi
- Central Institute for Medicinal and Aromatic Plants (CIMAP), Lucknow
- Regional Research Laboratory (RRL), Jammu.

In addition, four National *Jai Vigyan* S&T Missions have also been launched.

2.2 Human Resources Development in Biotechnology[1]

Post-graduate, post-doctoral, and post-MS/MD programmes are being implemented in 25 Indian universities. About 400 students are admitted annually, and 4300 students have graduated so far. Awards are being given to outstanding scientists and young bioscientists. Jawaharlal Nehru University holds a combined entrance examination for admission to two-year MSc programme in biotechnology in 18 participating universities.

3. BIOTECHNOLOGY INFORMATION NETWORK

Biotechnology information network (BISNET)[1] provides bioinformatics and bio-computing services to all concerned research laboratories and manufacturing concerns. It has 10 distribution information centres (DICs) and 38 distributed information sub-centres (DISCs) spread across the country. The apex centre at Department of Biotechnology provides for patent search in biotechnology. Training programmes are run in bioinformatics; diploma courses are being run in two universities.

Many universities, government institutions and pharmaceutical companies have formed bioinformatics groups (eg, BIOCON–Karnataka Govt–ICICI; CII–JNU; CCMB–Satyam Group; Nicholas Piranel—Centre for Biochemical Technology, Delhi)[2].

4. INTELLECTUAL PROPERTY RIGHTS, BIOSAFETY & BIOPRODUCTS[1]

Department of Biotechnology is supporting scientists for filing patents in biotechnology. The

National Bioethics Advisory Committee was formed some time ago under the chairmanship of Prof V. Ramalingaswami. Biosafety guidelines in r-DNA research are strictly followed. Institutional biosafety committees have been formed in all institutions. Department of Biotechnology is also implementing programmes on biotechnology benefits to SC/ST population, women and rural society, by forming demonstration-cum-extension type projects. These include developments in floriculture, mushroom cultivation, vermiculture and vermicomposting, spirula production, utilisation of agricultural wastes, environmental protection and awareness programmes. A model bio-village has been designed in Gujarat. A Golden Jubilee Womens' Biotechnology Park is being established in Chennai.

5. INTERNATIONAL COLLABORATION[1]

Several bilateral and multilateral programmes involving countries in Europe, Africa, USA and India, as well as UNDP, FAO, SAARC, and ASEAN countries have been progressing well.

6. BIOLOGICAL DIVERSITY BILL[1]

'The Biological Diversity Bill, 2000' has as its aim: 'to provide for conservation of biological diversity, sustainable use of its components and equitable sharing of the benefits arising out of the use of biological resources and for matters concerned therewith'. These aims are practically the same as were spelt at the Convention on Biological Diversity (CBD) signed at the 1992 Earth Summit at Rio de Janeiro. The Bill attempts to control transfer of Indian genetic resources to foreign parties and to protect traditional knowledge. It identifies 'heritage sites' which would be free of human use as well as lists threatened species. It provides for royalties to be imposed on enterprises in relation to patent rights. Some experts have felt that the Bill is excessively regulatory, negative, and not conducive to promoting enterprises; it is also silent on the Exclusive Economic Zone (EEC), an ocean area nearly two-thirds the land area, with rich resources.

7. PROGRESS ACHIEVED[1]

The following are the salient features of the progress achieved in biotechnology, with special reference to agriculture and health care:

7.1 Agriculture

It hardly need be emphasised that the agricultural sector provides for over a quarter of our national gross domestic product (GDP), with 150 million hectares under cultivation, providing employment to 120 million people. Our food production now is around 210 million tons, and having a buffer stock of over 30 million tons[3]. But there are disturbing trends. In spite of the Green Revolution, agricultural production has been plateauing over the past 2-3 decades. Forty per cent of crop production is lost due to weeds, pests, and pathogens. A major part of such losses that occur due to biotic and abiotic factors can be controlled through biotechnology initiative. With the growing population, agricultural production has to be doubled by 2005. The benefits of biotechnology have unfortunately not yet reached the farmer.

Although hybrid technology has shown its potential, the area under cultivation using hybrid seeds is only 15-20 per cent. In 1999, certified seeds were not available to 85 per cent of farmers who were supporting 85 biotechnology methods in their farms[4].

The Govt of India is spending Rs 14,000 cr on subsidies for fertilisers and pesticides. Today, Indians are consuming grains with 25 per cent chemical fertilisers/pesticides (the US ceiling is 2.5 per cent). Spurious insecticides worth Rs 6,000 cr are in the market[5].

In spite of all these constraints, the future prospects of biotechnology in India are encouraging. Many laboratories are engaged in plant molecular biology and genetic engineering research. It remains to be seen whether recent moves towards liberalisation of the economy would have a major impact on the future developments in the biotechnology industry. It is estimated by the Biotech Consortium of India that the distribution of biotech products would be as follows[6]:

Agriculture - 43 %

Health care - 40 %

Industry - 23 %

7.1.1 *Tissue Culture*

Micropropagation using tissue culture methods are ideal for rapidly multiplying the desirable types in vegetative propagation of plants at comparatively low cost. Many companies in India are producing plantation materials, mainly ornamentals. The aim of the Department of Biotechnology is to develop a package of technological protocols for forest trees, horticultural crops and plantation crops.

The national requirement of vegetatively multiplied seasonal crops species (eg, sugarcane, potato, banana, ginger, garlic, tapioca) is Rs 3000 cr/year. Tissue culture has not been a commercial success because of the high cost of *ex-vitro* plantlets (Rs 6-10 per plantlet). The Tata Energy Research Institute (TERI), New Delhi, has used tissue culture technique to develop nurseries containing fast-growing, hardy, high biomass plants under disease-free conditions for relocation to agricultural farms and forest areas. This concept has been successfully introduced in Maharashtra for sugarcane. Rural entrepreneurs can buy such plants from nurseries and cultivate these in their farms[7]. Tissue Culture Pilot Plants (along with Micropropagation Technology Parks) have been established at the National Chemical Laboratory, Pune and TERI, New Delhi, for eucalyptus, teak, bamboo, vanilla, and elite cardamom; technologies for 20 species are available. Gujarat has given the first hybrid cotton and tobacco to the world.

Department of Biotechnology has bought out a compendium of technologies for improving plant materials through tissue culture in the areas of forestry, horticulture and plantation crops.

7.1.2 *Transgenics*

In India, transgenic technology is gradually attracting attention. The Maharashtra Hybrid Seed Company (MAHYCO) has introduced Monsanto's insect-resistant Bollard Bi gene into the Indian cotton hybrids by back-crossing with a transgenic line; this variety has undergone encouraging field trials with encouraging results. TERI, New Delhi, is carrying out experiments on insect-resistant transgenic plants[8] like brinjal, cauliflower, cabbage, potato, tomato, etc. Transgenic plants carrying strains for resistance to insects, viruses, and diseases, as well as rich in nutritious quality, are under development. Various ripening-related genes from banana have been cloned. Encouraging results have been obtained in producing transgenics of mustard, tobacco and chicken pea.

It is expected that a genetically engineered variety of potato rich in protein, developed at the National Centre for Plant Genomic Research (NCPGR), JNU, New Delhi, will be available in the market soon[9].

As part of its collaborative programme in the International Rice Genome Sequencing Programme, Department of Biotechnology has chosen chromosome 11 for intensive studies as it carries important genes for disease and pest resistance as well as for high quality. Indian Agricultural Research Institute (IARI), and University of Delhi are involved in this Rs 50 cr project.

A report on genetically modified crops, 'Transgenic plants and world agriculture', has been prepared by 7 academies, viz., the Indian National Science Academy (INSA), and those from Brazil, China, the Royal Society of London, the Third World Academy of Sciences, and the US National Academy of Sciences. The report puts this technology in perspective, looks at its benefits, and addresses issues of concern. Progress in genetic transformation is slow because the procedures for some of the important legume crops are still not available.

7.1.3 *Seribiotechnology*

Department of Biotechnology and Central Silk Board have identified thrust areas in sericulture (both mulberry and non-mulberry) where biotechnology can play a role. Immunodiagnostic tests have been developed for early detection of

diseases in silkworm. Artificial diets for rearing silkworm larvae as well as transgenic silkworm larvae have been developed. A silkworm genome project has been initiated.

7.1.4 *Animal Biotechnology*

Programmes on embryo transfer, nutrition, health, diagnosis, vaccines and leather biotechnology have given promising results. Technology transfer for some of these developments is in progress. Cows produced through embryo transfer have come into production (3,000 to 6,000 l per lactation). Collagen sheets developed for wound healing applications have undergone successful clinical trials.

7.1.5 *Aquaculture & Marine Biotechnology*

Diagnostic kits for detection of bacteria in food and dairy products have been developed. Mantle tissue culture technology has been evolved to produce *in vitro* marine pearls. Immunomodulators for shrimp are being evaluated. Advances have been made in prawn aquaculture and hatchery technology.

7.1.6 *Food Biotechnology*

Work is on for low cost nutritional supplements for malnourished children using biotechnological approaches, protocols for detection of food toxicants and contaminants, biodegradable eco-friendly packaging films for preservation of fresh fruits and vegetables. A National Food Safety Facility has been established at the Central Food Technological Research Institute (CFTRI), Mysore.

7.1.7 *Microbial Biotechnology*

Technology development for microbial enzymes active in extreme temperatures, novel antibiotics, and bioactive molecules has been undertaken.

7.1.8 *Biofertilisers*

A mission-mode project has been launched on technology development and demonstration of biofertilisers – blue-green algae (BGA) – including *Azolla* and *Rhizobium*. Technologies have been developed for blue-green algae production. Increase in yields (by 5 to 15 per cent) have been found by use of blue-green algae as biofertiliser for paddy, pulses and oilseeds.

7.1.9 *Bio-control Agents*

Eight new pesticides have been developed. Two pilot plants have been set up, and about 20,000 farmers have been involved in the trials. Technologies are being transferred to industry on a regular basis.

7.1.10 *Bio-prospecting*

Multi-institute and collaborative programmes are in progress for characterisation and conservation of different eco-geographical regions. Remote sensing techniques are being used. Maps of regions of special interest (such as northeastern Himalayas and southwestern Ghats) are being prepared.

7.1.11 *Biodiversity Conservation & Environment*

Four technologies for environmental monitoring based on DNA probes and enzyme-linked immunosorbent assay (ELISA) techniques have been developed. Several techniques have shown promise for beneficiation of high sulphur content coal, manganese, and coal mine spoil dumps.

For conservation of endangered plant species, techniques for extraction of nuclear DNA, tissue culture for endangered mangrove species, nursery to raise plants of Indian desert, and collection of germ plasm of rare desert plants have been developed.

8. HEALTH CARE

Fourteen genetic clinics for molecular diagnosis and counselling for some common genetic disorders (such as beta-thalessemia and Duchenne muscular dystrophy) are providing prenatal diagnosis. A programme on Functional Genomics has been launched at the Centre for Biochemical Technology, New Delhi to identify novel mutations in known genetic disorders in the Indian population. India has a vast number of inbred communities in various parts of the country which

offer unique human gene pools for study of genetic diseases.

The Centre for DNA Fingerprinting and Diagnostics (CDFD), Hyderabad does DNA profiling and analysis, which have found applications in crime detection and establishment of paternity in disputed cases. CDFD has completed DNA fingerprinting in 300 cases. Department of Biotechnology has formed a task force on the Indian Genome Project (IGP).

The National Centre for Cell Sciences (NCCS), Pune, identifies, maintains, propagates and supplies human cell lines. It has established the technology for collection and supply of human organs like cornea, skin and bone marrow. Technologies for growing large sheets of skin from small pieces removed from unaffected areas and their grafting have been successfully tried in hospitals. The molecular mechanism of how *Salmonella* bacteria survive in phagocytes has been elucidated.

A large number of institutions are working on medicinal biotechnology. Some indigenous medicinal plants have shown promise as immunomodulators. Development of cholera vaccine using recombinant DNA technology is under hospital trials. A chemotherapeutic immunomodulator for leprosy vaccine developed at the National Institute of Immunology, New Delhi, is being produced commercially. Indigenous AIDS diagnostics have been developed and the technology transferred to industry. Similar diagnostic kits have also been developed for around 14 communicable diseases. Bharat Immunologicals and Biological Corporation Limited (BIBCOL), Bulandshahr, is making oral polio vaccine and other immunobiologicals which are under trial. Indian pharmaceutical industries which have little R&D expertise find it more attractive to sell imported kits than developing indigenous ones.

The National Brain Research Centre (NBRC), New Delhi will undertake research in frontier areas like learning, memory, ageing and artificial intelligence. The National Institute of Immunology, New Delhi, conducts research on defence mechanisms of the body to facilitate development of innovative prophylactics, diagnostic and therapeutic measures for health care delivery, as well as research on reproductive biology.

The Rajiv Gandhi Centre for Biotechnology at Thiruvananthapuram (which started functioning in 1994) is conducting research on agents responsible for communicable diseases, understanding of basic physiological phenomena involving molecular endocrinology, molecular immunology, genetics, cell biology, development and differentiation and neurochemistry-related brain function. Since Kerala is a major centre of biodiversity and unexplored tropical microbes and parasites, it would also be giving major thrust to studies in this field.

The International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi, is involved in research in the areas of mammalian biology (especially malaria, virology, immunology and recombinant gene products) and plant biology (specially understanding mechanisms of biotic and abiotic stresses in plants to develop technologies for gene transfer in crop plants).

9. CONCLUSIONS

Realising the potential of biotechnology in providing solutions to problems of health, agriculture, food production, environmental protection and biodiversity conservation which are vital for India and other developing countries, a major programme has been embarked identifying thrust areas of relevance, establishing the infrastructure, developing specialised manpower, and encouraging interactions between academic and research institutions, industry and entrepreneurs. The Department of Biotechnology is providing adequate financial support and other inputs for the growth of technology and its applications, and trying to remove some of the bottlenecks that have come to notice. India can confidently look forward to reaping the fruits of this powerful technology in the years to come.

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