Environmentally Sound Biotechnology

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THE rapid increase in population is imposing enormous stress on environment. The projected world population would be 6,147 million by 2000 AD. Out of this, 4,884 million people would be in the developing countries. The figure for India would be 994 million. Although the world food-production capacity has been increasing steadily, the global food-security situation is far from satisfactory. According to an FAO report of 1979, the net cereal deficit in developing countries will increase to 144 million tonnes by 2000 AD. By that time 7% of the population of these countries will be undernourished. In this context, it is important to consider the areas where biotechnology can play an important role.

Biotechnology has revolutionized the current status of knowledge of a number of biological pathways and processes applicable to the biological principles for human welfare and better quality of life. It has given us a better insight into the molecular basis of a host of genetic disorders, syndromes, and the immune system at the cellular and molecular levels. It has also helped us in devising methods to modulate the immune systems for many of the species of plants, animals and microbes.

Biotechnology would substantially contribute to development through better health care, enhanced food productivity through sustainable agricultural practices, improved bioprocess technologies, development of biofertilizers, biocides and bioleaching, efficient industrial development processes for transforming raw materials, improved supplies of potable water, support for sustainable technique of afforestation and reforestation, and the detoxification of hazardous material.

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Opportunities for Global Partnership

Biotechnology offers new opportunities for global partnership especially between the countries which have rich resources but have not fully developed technologies and those which have developed technologies and can transform biological resources to serve the needs of sustainable development.

There is a need for a global agreement on safety framework to ensure the development of environmentally sound management and sustainable application of biotechnology.

International and regional co-operation is needed on policy issues relating to conservation and exchange of germplasm, intellectual property rights, bio-safety procedures, collaborative research programme and acceleration of technology acquisition, transfer and adaptation.

Sustainable Agriculture

Crop Improvement

To ensure sustainable agriculture, there is a need to accelerate plant and animal breeding procedures, improve micro-organisms using traditional and modern biotechnologies, improve the productivity of food and animal-feed products, develop stress, disease and pest resistant plants, increase the efficacy of symbiotic nitrogen fixation, exchange germplasm, develop diagnostic agents and vaccines, identify productive strains of fast-growing trees for fuelwood, and evaluate biotechnological methods to improve fish, algal and other aquatic species.

The insertion of foreign genes into cells has made it possible to circum-

vent conventional barriers of genetic incompatibilities and create varieties with entirely new characteristics and functions. The use of recombinant DNA technology (r-DNA) as well as somaclonal variations, protoplast techniques, clonal propagation including micropropagation, organogenesis and somatic embryogenesis provide opportunities to bring new value-added, stress-tolerant, disease- and pest-resistant varieties of crops. Transgenic plants and animals can now be produced with desired characteristics. Immunodiagnostics will help in the detection of diseases in plants and animals. Embryo-transfer technology offers great scope for improving the productivity of milch and draught animals.

Through application of r-DNA in agriculture it has been possible to transfer some important traits, including resistance to stress, herbicides and pests, better crop growth, increased photosynthesis and stimulation of nitrogen fixation.

Policies and programmes have been drawn up to explore the potentials of biotechnology for improving agricultural productivity, reclamation of poor soils, and introduction of non-polluting and cost-effective biological pesticides. The main thrusts include crop improvement, crop protection and tissue culture. In crop improvement, in the long term biotechnology has application in:

- Development of salt-tolerant and drought-resistant crops.
- Development of nitrogen-fixing crop varieties.
- Introduction of crop varieties with higher photosynthetic efficiency.
- Improvement in the quantity and quality of storage proteins.
- Production of high-yielding hybrid seeds.

In crop protection, the development of disease-resistant varieties of transgenic plants, herbicide-resistant plants and r-DNA-based diagnostic reagents for the identification and treatment of viral, bacterial and fungal diseases are the major areas of interest.

Courtesy: IARI

From a very late-maturing, excessively tall exotic accession of *Brassica juncea*, an early-maturing somaclone was developed which has resistance to white-rust and downy-mildew and outyields the widely grown 'Varuna' mustard. Some selections isolated from this 'Bio 902' mustard have attractive bright-yellow seeds containing 49-50% oil.

Genetic manipulation can produce varieties with greater tolerance to herbicides, soil toxicity, salinity, pests, diseases and drought. In plant tissue culture, substantial progress has been achieved in clonal propagation, micropropagation, somatic embryogenesis and somaclonal variation in agricultural, horticultural and plantation crops.

The current applied recombinant DNA projects in agriculture deal with (a) micro-organisms that are conducive to plant growth, act as insecticides, or confer frost resistance, and (b) plants genetically engineered for disease resistance, or to ward off damage by insects or herbicides.

Genetic engineering techniques would manipulate genetic expression and construct new plant types having tolerance to biotic and abiotic stresses and can adapt themselves to different climatic conditions. Excessive deforestation, soil erosion, waterlogging, increase of soil salinity, extensive use of chemical fertilizers and pesticides, migration from rural to urban areas and industrialization are increasing rapidly, leading to a loss of productive land. For all these problems, major scientific solutions lie in new biotechnological approaches focussing not only on agricultural production, but also on rehabilitation and employment generation in the fields of post-harvest technologies, food processing, and production of value-added products.

A number of methods are now available to produce transgenic plants which include a modified Ti-plasmid system in *Agrobacterium tumefaciens*, direct gene transfer including PEG-induced DNA uptake, microinjection of DNA into cultured cells and plant organs, electroporation, and microprojectile bombardment.

Biofertilizers

Biofertilizers would reduce our dependence on chemical fertilizers and decrease the input costs. A project on technology development and demonstration on biofertilizers covering blue-green algae and *Rhizobium* has been formulated by the Depart-

ment of Biotechnology. The use of blue-green algae for wetland rice cultivation and *Rhizobium* for legumes and oilseed crops would bring down the cultivation costs, ensure soil fertility on a long-term basis and increase productivity. There is a need to develop a large-scale production technology and encourage entrepreneural activity.

Rhizobium melilotii has been developed which has improved the nitrogen-fixing properties of alfalfa. It will also reduce the ground-water pollution from the over-use of nitrogen fertilizers.

Biological Control and Integrated Pest Management

Genetic engineering provides scope for breeding for pest resistance, as well as for the use of biocontrol agents. The identification and exploitation of exotic genes that provide resistance to insects is one of the significant contributions of genetic engineering to crop production and improvement. Most exotic insect-resistance genes are insecticidal proteins where the gene product itself is toxic.

Crop losses due to pests and diseases are very high in India, amounting to over Rs 60,000 million annually. Most of the chemical pesticides have a potential pollutant effect. Hence biocontrol as an alternative strategy is gaining importance.

Microbial pesticides are now available in which bacteria or other microorganisms containing an intracellular protein biotixin is treated chemically to kill and fix the cells, thus stabilizing the biopesticide.

Pseudomonas syringae, a bacterium present on the leaves of plants, contains a protein that facilitates the nucleation of ice crystals, leading to frost damage to plants. Using recombinant DNA techniques, strains of *P. syringae* have been constructed that lacked ice-nucleating-protein gene. When sprayed on crops, the 'ice-minus' bacteria compete with natural populations of ice-nucleating bacteria on leaves, thereby reducing their concentration and lowering the temperature at which plants would suffer frost damage.

Plant have been successfully engineered for resistance to disease and insects. Tobacco plants have been genetically engineered for resistance to crown-gall disease. Tobacco plants resistant to caterpillars and various forms of herbicide have been genetically engineered. Tests have been carried out on plants made tolerant to attack by tobacco-mosaic virus by inserting a gene encoding its coat protein. In tomato, genetically altered plants have been produced by the addition of a single gene coding for insect-control protein of *Bacillus thuringiensis* against tomato hornworms and fruitworms. In addition, tomato plants have been genetically engineered for tolerance to herbicide glyphosate with a resistance gene from Petunia.

Baculovirus epizootics are often a major factor in the natural control of insects. It has been clear now that insecticidal efficacy can be improved by the introduction of biotoxic genes into the viral genome, and that environmental containment of the genetically engineered virus can be assured by replacing a gene required for viral inoculation with foreign biotoxin.

Genetic engineering brings new tools for pest control and enables other tools such as integrated pest management (IPM) to be used more effectively. IPM offers an alternative approach of introducing parasites and predators of the target pest species.

Biomass

Our forest cover is progressively shrinking, and simultaneously the demand for wood-based material is increasing. Biomass is critical not only for the supply of fuel and fodder but also to meet the needs of paper, pulp and fibres. Well-conceived production programme have been evolved for developing high-yielding certified planting material from genetically superior trees, for evolving strong research and development base, and for employing tissue culture and other biotechnological tools.

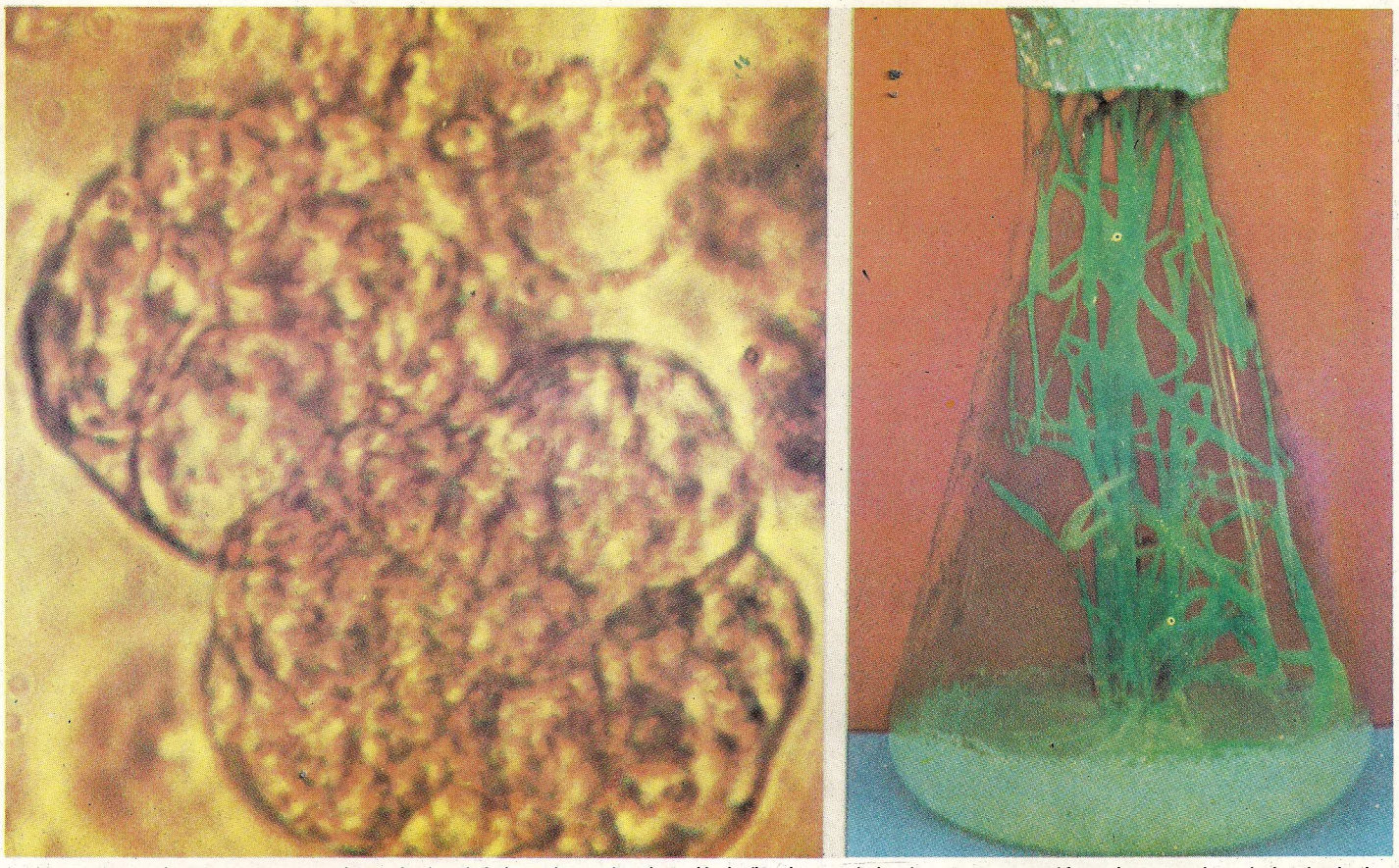
The Department of Biotechnology has set up two pilot plant units at NCL, Pune and TERI, New Delhi, with the main objective of carrying out large-scale multiplication and micropropagation of a few million plantlets of elite forest tree species, including *Eucalyptus camaldulensis, E. tereticornis, Dendrocalamus strictus, Tectona grandis*, bamboo, *Populus, Leucaena* and *Acacia*. A few thousand tissue-culture-raised plantlets have been sent to different states for field demonstration trials.

Plantation Crops

Plantation Crops are high-value commercial crops that play a vital role in the country's export trade. They occupy 1.82% of the total cropped land and generate an income of Rs 16,000 million. Plantation crops have opened up considerable avenues for employment and systematic labour. The Department of Biotechnology has identified a few important crops, including spices, tea, coffee and rubber, on which research and development efforts would be concentrated.

Improving Human Health

Multidisciplinary efforts are needed to develop programmes and policies related to sound management of bio-technologies towards improving human health. At the global level, collaboration is needed between research institutions and industries in strengthening research, development and transfer of technology relating to diagnostic, biological therapeutics and vaccines. Management-related activities including monitoring the drinking-water quality, development of immunodiagnostics, detection of



Courtesy: H.S. Gupta, ICAR

In a protoplast-culture programme, microcolonies (left) have been developed in *indica* rice, and plantlets regenerated from the protoplast-derived colonies (right).

viral, parasitic and bacterial pathogens, production of vaccines against major communicable diseases, biological control agents for disease-transmitting vectors, development of drugs for resistant organisms, improved delivery systems for therapeutics and prophylactics, methods for treatment of genetic disorders and effective utilization of medicinal plants. Efforts are also needed to develop mass awareness and understanding of biotechnology.

Improving human health is one of the most important objectives of development. The deterioration of environment through air, water and soil pollution, as well as by toxi chemicals, hazardous wastes and radiations, is a matter of growing concern all over the world. In developing countries, malnutrition, population growth, poor human settlements, inadequate sanitation and lack of potable water add to the problems of diseases. All these factors need an effective and appropriate application of biotechnology for development.

Priorities should be laid on the prevention and control of tuberculosis, leprosy, poliomyelitis, diarrhoeal and respiratory diseases, viral hepatitis, malaria, amoebiasis, filariasis, and giardiasis. As per the data of the World Health Organization, more than 10 million people are suffering from tuberculosis and about 5 million from leprosy. One in every 40 million people die of malaria every year. In addition there are about 5 million people suffering from Chagas' disease. The majority of the children in developing countries die of diarrhoea and bronchial pneumonia. To provide better health for all by 2000 AD, chemists, physicists and biologists should work for the eradication of diseases. Special efforts are needed to develop programmes for specific treatment and protection from all types of cancers, heart ailments, skin and other diseases. In a number of countries, special attention is given to determine the causes of non-communicable diseases, life-style, environmental health risks, nutrition, growth, ageing and health-care systems. Environmental risks can be reduced through enactment of new legislations and establishment of norms, counselling and stimulating voluntary activities. The implementation of programmes requires governmental and political support.

Areas where biotechnology has already made a significant impact include pharmaceuticals, genetically engineered vaccines, growth hormones, interferon for treatment of

viral diseases and cancer, antibiotics, bioactive molecules, speciality chemicals, improved drug-delivery systems, and immunodiagnostics. The use of monoclonal antibodies and molecular probes have helped in the better understanding of a number of diseases, including diagnosis, prognosis and therapy of human tumors. Strategies for gene therapy include gene replacement, correction and augmentation. A number of contraceptives are undergoing clinical trials. Drug-directing agents, monoclonal antibodies, magnetic microspheres, immobilized enzymes and cells, diagnostic reagents such as enzymes and monoclonals are the products of biotechnology. Biomedical engineering products include biomaterials such as artificial skin and biomedical equipment like artificial kidney machines.

Vaccines

Biotechnology has the potential of producing more effective vaccines against various viral, bacterial and parasitic diseases by using new emerging technologies such as recombinant live-vector vaccines and recombinant DNA subunit vaccines. These vaccines have proved advantageous where conventional vaccines like attenuated or inactivated vaccines, peptide-based or live vaccines present problems. Recombinant vaccinia virus vaccine with expression of foreign antigens may prove useful in the immunoprophylasis of infectious diseases of both human and veterinary importance. Depending on the type of vaccine used, these vaccines activate the humoral and cell-mediated immune response.

Bioactive Molecules

Several bioactive molecules have been produced on a commercial scale by microbial methods by incorporating the required genes into the various expression systems like *Escherichia coli* and yeast. These molecules include production of insulin, interferon, tumor-necrosis factors, serum proteins, interleukin-2, protein-A, tissue plasminogen activators and growth hormones. Human and animal growth hormones have been used for promotions of growth, and healing of burns and fractures. Urokinase and streptokinase are the two most widely used thrombolytic enzymes. A number of neuroactive peptides, lymphokiness and other regulatory proteins and hormones are also being produced.

Scymnus frontalis (left) and *Coleomagilla maculata* (righ
pests and diseases is inexpensive. There is no pollution

A healthy crop of rice has been raised in Pune from fields to which nitrogen-fixing blue-green algae have been applied. Besides blue-green algae, scientists are increasingly using Azotobacter, Azospirillum and Azolla (Latin: Azo, no nitrogen) to partly replace high-cost chemical fertilizers derived from non-renewable resources.

Molecular Probes

Molecular probes in solid tumor and monoclonal antibodies have emerged as the most important tools in the diagnosis, prognosis and therapy of human tumors. Monoclonal antibodies may also be labelled with radioisotope material for diagnostic purposes as well as therapeutic ends. Recent advances in hybridoma technology, genetic engineering, isotopic and non-isotopic immunoassays have increased our understanding of the molecular genetics of many disease conditions. Molecular probes have been successfully used in

Scott Bauer, USDA

beetles are seen feeding on pea aphids. Biological control of
f environment nor is there a risk to human health.

the diagnosis of a number of viral, bacterial and parasitic infectious diseases and plant disease agents such as viroids, viruses and mycoplasmas.

Synthetic allele-specific oligonucleotide probes are being used to detect point mutation in prenatal and carrier diagnosis of the hereditary prophyrias and anti-trypsin deficiency.

Non-radioactive probes based on ribosomal RNA provide a powerful means of microbe detection. DNA-anti-microbial resistance genes are important in anti-microbial therapy and control of infection.

Monoclonal Antibodies

Recent improvement in the production of antibody-secreting hybridoma cells by cell-fusion technology has revolutionized biology and medicine. Today, monoclonal antibodies specific for almost any antigen can be generated, setting the stage for many different applications. The high specificity of antibodies for antigens has long attracted the interest of scientists in the field of protein purification. The rapidly increasing availability of monoclonal antibodies has stimulated their use in the immunoaffinity chromatography of therapeutic proteins and the interest of licencing authorities.

Catalytic Monoclonal Antibodies

Catalytic monoclonal antibodies (cat-MABs), with unlimited range of recognition site structure, provide potentially an enormous repertoire of new catalytic agents, and have become an important biotechnological tool. Cat-MABs have wide applications, especially where no suitable enzymes or chemical catalysts are currently in use. Some of its potential applications are in the synthesis of organic fine chemicals, as biosensors, and in protein-engineered applications such as cleavage of leader sequences and other extraneous domains in recombinant proteins or for post-translational modifications of proteins.

Immunodiagnostics

To develop simple, sensitive and reliable methods, kits are being developed for the diagnosis of viral, bacterial and parasitic diseases. In India diagnostic kits are being developed for the early detection of pregnancy, filariasis, hepatitis-B, amoebiasis, toxoplasmosis, brucellosis, tuberculosis, leprosy, typhoid fever, malaria, giardiasis, leishmaniasis, rotavirus and shigellosis.

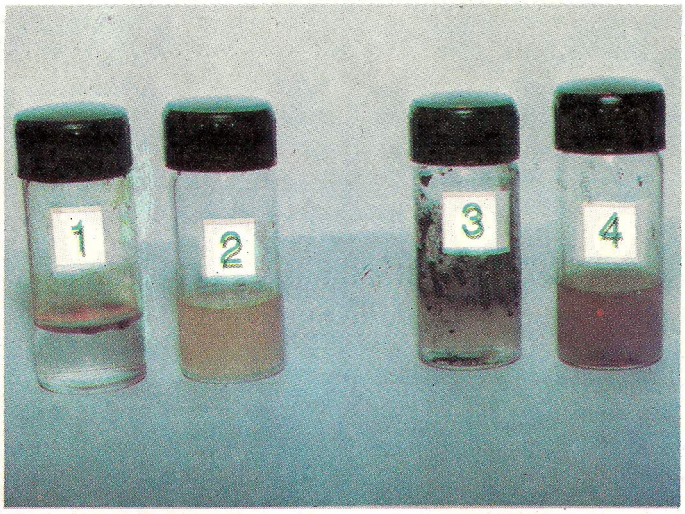
A number of diagnostics are available for veterinary diseases such as brucellosis, foot-and-mouth disease, infectious bovine rhinotracheritis, blue-tongue, rinderpest, rabies and certain cancers.

Hybrid Antibodies

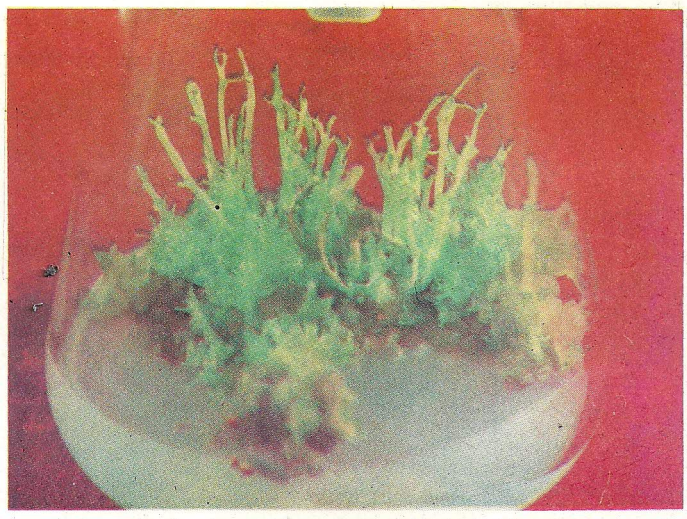
Using a fragment which contains the heavy- and light-chain-variable domain, immunotoxins are obtained through construction and expression of single-chain antibody toxin fusion proteins in *Escherichia coli* which are homogenous, specific and more cytotoxic in nature. Using this technique, it is possible now to create recombinant immunotoxins with a number of other antibodies. Some of the recent applications of immunotoxins have been in the treatment of diseases

To develop disease-resistant mungbean through tissue culture exploiting somaclonal variation, multiple shoots have been induced in 'Co 5' mungbean.

Courtesy: Sree Rangaswamy, TNAU



When treated with a biosurfactant produced by *Mycoplasma* sp. (BS1), crude oil (1) and oily sludge (3) have shown emulsification (2 and 4).



Courtesy: J. B. Choudhary, HAU

In an attempt to develop chickpea types with desirable agronomic traits and resistance to blight and wilt, a cell-line with a high morphogenetic potential has been selected.

involving interleukin-2 receptor positive cells, allograft rejection, acquired immune deficiency syndrome (AIDS) and epidermal growth factor.

Drug Delivery

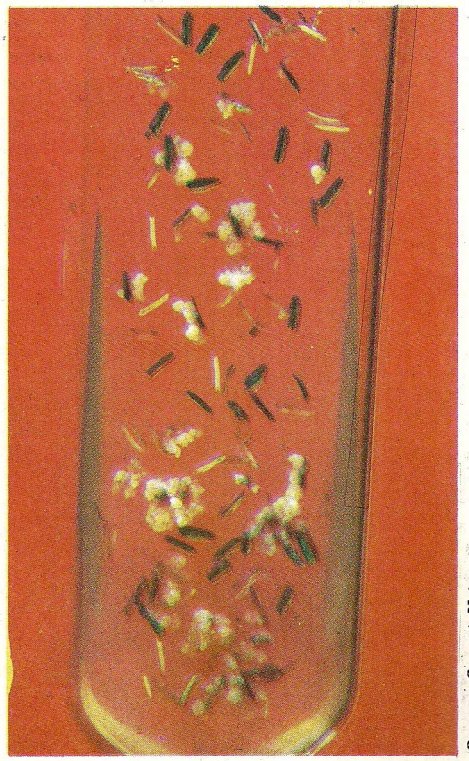
Most of the new generation of therapeutic drugs are peptides or proteins which are easily broken down by the body unless they are protected in some way. New technologies for delivering drugs lay emphasis on maximizing the time the active ingredients are present in the drugs. With the exception of monoclonal antibodies, most of the new delivery vehicles are synthetic. Some new drug-delivery systems for transdermal use are: (i) bioerodable non-toxic synthetic polymer of 5 to 300 microns, (ii) transdermal applications like nitroglycerine for treating angina, (iii) scopalamine for combating motion sickness, and (iv) microsponges made of synthetic polymer spheres of 5 to 300 microns. In addition, liposomes are used for delivery of drug by oral route, ocular application and injection. Liposomes are synthetic as well as natural. Liposome intercalcated drug formulations using amphotericin-B (for treatment of fungal infections), doxirubicin hydrochloride (anti-tumor and anti-cancer drug), rifampicin (for treating tuberculosis) are already in use.

Gene Therapy

Recent advances in molecular genetics have provided a new approach towards the therapy for human genetic diseases through a direct attack on mutant gene in order to replace or supplement defective genetic information with normal functional genes. Efficient gene transfer *in-vitro* and *in-vivo* and genetic correction by site-specific targetting of many gene-related genes have become feasible. Gene therapy has been useful for disorders of the bone marrow, liver, central nervous system, cancer, and deficiencies of circulating enzymes, hormones and coagulation factors.

A gradual progress is being made towards identifying genes of interest by making use of a range of strategies which will provide an insight into basic processes of lymphocyte differentiation and open up the possibility of somatic gene therapy. Already location of genes for human X-linked immunodeficiencies have been identified for better understanding of the molecular basis of characteristic impairment of T- and B-cell differentiation.

Callus initiation is seen from anthers of *indica* rice. Anther-cultured double-haploids of 'AC 561' and 'AC 570' recorded 15% higher yield. A somaclone of 'Annada' yielded 15% more than the parent. Three other somaclone lines showed high resistance to sheath-blight.



Courtesy: Osmania University

Chemical Hazards

The world today is producing over 10,000 new chemicals every month. Over 50,000 to 70,000 chemicals are used extensively in millions of dif-

ferent commercial products. These chemicals include toxic substances which are responsible for different types of allergies and cause damage to the vital organs of the human body like the eye, brain, liver, kidney and reproductive organs. They may also produce malformations in unborn children and even generations to come. A good number of such chemicals are also carcinogenic and even small quantities of these are harmful to the human body. Such chemicals are widely being used as pesticides, fertilizers, dyes and pigments, pharmaceuticals, organic chemicals including petrochemicals, steel, nonferrous metals like copper, lead and zinc, and caustic soda.

Industrialized agriculture has promoted an extraordinary use of these dangerous chemicals in the form of pesticides, weedicides and fertilizers. Residual effects now appear on all variety of foods, including fish, fruits, vegetables and milk. Chemical hazards are also now encountered in the non-industrialized use of chemical products like plastic water-storage tanks. They constitute a source for the diffusion of toxic chemicals, and their impact on rural ecosystem is still being assessed. The use of biofertilizers, biopesticides and biopolymers may help reduce the danger from these chemical toxins.

The problem of toxic hazards is already reaching alarming proportions and it may increase with industrialization. Legislations in our country are inadequate to deal with the emerging safety problems which arise at the stage of chemical manufacture, import, storage, transport and handling. There is an urgent need to assess the hazards posed by exposure to chemicals at the work-sites and in general environment and to set suitable limits for safety.

Marine Pollution

Humans are exposed to marine pollutants through the consumption of fish and other sea food, and also while they are swimming, bathing or having direct contact with sand or sea water. Exposure of viral or bacterial pollutants generally causes short-term effects, whereas exposure to chemical pollutants has long-term effects. The consumption of sea food contaminated with sewage has been the cause of many outbreaks of gastrointestinal diseases. Oil spillage is yet another cause of environment pollution with direct effect on human health. It is important to ascertain the extent of these problems. A comprehensive action plan by international agencies, private bodies and the affected countries is necessary.

Bioenvironmental Control of Mosquitoes

Mosquito-borne diseases are rapidly growing. They include malaria, japanese encephalites, dengue and filariasis. There have been a number of reports of major epidemics of cerebral malaria, dengue and japanese encephalites. Major efforts are required to control them through integrated management programmes.

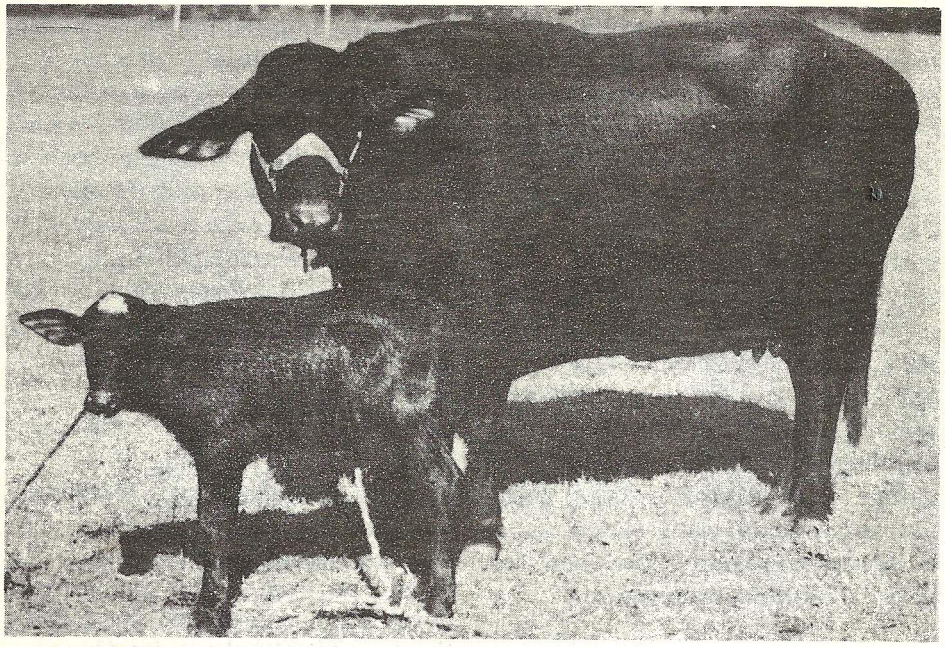
In the control of malaria, the strategy comprises the application of biological systems and environmental management methods for control of mosquito breeding, involving the community. The control strategy is designed after the studies of the epidemiological investigations of the disease transmission. In India, 12 centres are working in different agroclimatic conditions. This approach has contained the incidence of malaria significantly in all these regions and reduced our dependence on insecticides.

Environment

Environmental protection is an important component of sustainable development. Continued use of chemicals, energy, renewable and non-renewable resources by the ever-increasing population is associated with environmental problems. Environmental damage as a result of over-consumption of resources and high quantities of waste generated would keep on increasing despite our efforts to prevent waste accumulation and resort to recycling. Biotechnology can play an important role in the rehabilitation of degraded ecosystems and through development of new technologies for reforestation, germplasm conservation and new plant varieties.

Environmentally sound management and development measures aim to reverse environmental degradation by supporting safety procedures, developing processes for making optimal use of natural resources by recycling biomass, recovering energy, and minimizing waste generation. It requires the use of measures for waste treatment, soil conservation, reforestation, afforestation and soil rehabilitation. Application of biotechnology can help conserve environmental integrity through ecological security and conservation of biological diversity. Management-related activities include development of products and processes to minimize synthetic chemicals, reduce waste generation, recover energy, remove pollutants from the environment, making available sufficient planting materials for use in afforestation and reforestation, availability of stress-tolerant planting material, integrated pest management through biocontrol agents, use of biofertilizers and technologies for the treatment of sewage and organic wastes. Efforts in this area require human resource development and enhanced biotechnological co-operation between the developing and developed countries.

Conservation of national resources depends on a large number of ecological factors and the ability of these resources to sustain agriculture is being diminished as a consequence of over-exploitation and area extension. Increasing population offers the



Courtesy: G.D. Joshi, NDRI

The first test-tube-fertilized buffalo calf, named Pratham, is seen with the surrogate mother at the Embryo Biotechnology Centre of the National Dairy Research Institute, Karnal.

greatest threat to environment.

The problem of environmental pollution shows extreme complexity in India. Industrial pollution mostly affects the population of the major urban centres. In the rural areas the major effect on the environment is in terms of utilization of biomass (wood) and dung as energy source. This results in large-scale deforestation leading to soil erosion. At the same time, utilization of animal dung as an energy source precludes its use as manure, and this ultimately results in lowering of soil productivity. River pollution affects the country as a whole.

Biotechnology is likely to be one of the major tools in protecting the environment in India. Technologies ranging from tissue and cell culture to improved fermenter design for waste treatment would be important. Development and culture of specialized microbial strains for removal of pollutants is another area that requires attention. There is also scope for development and utilization of biohydrometallurgy. Immuno-diagnostic kits and genetic probes in water-monitoring would greatly help in maintaining the quality of potable water leading to improvement of public health.

The tools of biotechnology can also be applied to various economic sectors such as production of food crops, livestock, pharmaceuticals, conversion of biomass into energy, transformation of agricultural, industrial and human wastes, pollution control and environment sanitation. More important, there would be a direct and indirect impact on employment opportunities through generation and application of biotechnology.

Programmes in the area of environmental biotechnology such as biotechnological conversion of methane into methanol, microbial desulphurization of fossil fuels, and conversion of wastes into value-added products are generating important tools for environmental monitoring. Programmes for enhanced recovery of oil using biotechnological approaches and use of recombinant DNA application to oil-spill degradation and pollution control are being launched to increase the use of living biological systems so as to reduce our dependence on chemicals and hazardous processes.

New techniques based on biosorption—a process where solids of natural origin like micro-organisms, alive or dead, or their derivatives are employed for sequestration of heavy metals from an aqueous environment—are being used for removal and recovery of strategic and precious heavy metals from industrial wastes.

Environmental Monitoring

Recent developments in biotechnology hold great promise in the development of rapid, reproducible, portable and inexpensive methods and techniques for environmental monitoring. These systems include development of biosensors, and membrane bio-probes for heavy metals, insecticides, pesticides, radionucleotides and other contaminants, as also inorganic and organic pollutants in waste-water. Better sensors would be specially useful in the control of industrial bioprocesses. Biosensors are useful for on-line monitoring of biotechnological processes like conversion of methanol from methane. Environment monitoring also requires development of portable kits for detection of enteric protozoa, bacterial and viral pathogens in water samples using techniques of immunofilteration, immunoprecipitation and use of genetic probes for safe drinking-water.

Energy

Biotechnology plays an important role in energy production. Through biodegradation and subsequent fermentation, cellulosic and agricultural wastes have been used to produce fuels such as ethanol and butanol. Methanogenic bacteria help in the production of biogas from agricultural and animal wastes. Use of drought-resistant fast-growing plants and trees helps in the afforestation of wastelands.

Biocides

Vector-borne diseases—especially mosquito-borne ones such as malaria, filariasis, encephalitis and dengue fever—are the major public-health problems in developing countries. In India chemical insecticides cause large-scale environmental pollution. As an alternative to control disease vectors, biological control through the use of biocides has received particular attention in recent years. In research sponsored by the Department of Biotechnology, encouraging results have been obtained in the development and use of biocides as anti-larval agents for mosquito control. The Malaria Research Centre has successfully undertaken an Integrated Bioenvironmental Vector Control Project using larvivorous fish to control breeding sites, apart from the integrated management of the environment.

Microbia-enhanced Oil Recovery

Conventional oil-extraction technologies help us to recover only about 50% of the subterranean oil reserve. The rest of the oil is either trapped in between the rocks or is too viscous to be pumped out. Efforts are being made to improve oil recovery through microbial-enhanced oil recovery (MEOR). A number of approaches have been adopted, which include stimulation of endogenous micro-organisms by injecting nutrients into the wells; addition of laboratory-tested micro-organisms; and production of micro-organisms of specific biological compounds and their subsequent use in the wells. Efforts are being made to utilize micro-organisms that can use less-valuable parts of the oil as a carbon source to produce surfactants or emulsifiers to lower the viscosity of the oil without any impact on quality and cost of production.

Problems of Releasing Genetically Engineered Organisms

Application and release of engineered organisms into environment could lead to ecological consequences and potential risks unless necessary safeguards are taken into account and appropriate containment facilities provided. Biowastes from the industry and experimental conditions should be properly treated. The pathogenicity of the genetically engineered products should be rendered harmless before releasing in the environment. Facilities should be created for disposal of experimental animals through incineration.

Prior to the application of r-DNA-modified organisms to agriculture and environment, the properties of the organism, its interaction with other disease-causing agents and the infected wild plant species may be evaluated in terms of defining potential risks. It is necessary to access the bio-hazards of viral, bacterial and insecticidal agents meant for field application. All releases of r-DNA-modified strains for field testing should be done with the permission of a Genetic Engineering Approval Committee.

Application of biotechnology in environment management aims to enhance safety in technology development and application through international co-operation, with particular reference to social, health and environmental considerations. Procedures should be devised for risk assessment and risk management before genetically modified organisms are released into the environment. Activities in this area need to accelerate the environmentally sound application of biotechnology, especially in developing countries, with particular reference to guidelines of 'International Co-operation on Safety in Biotechnology'.

Enabling Mechanisms

Development and application of biotechnologies require major efforts to build up institutional capabilities at national and regional levels. Emphasis should be laid on training capacity, technology development, research and development facilities, industrial capacity, venture capital and expertise in the areas of marketing research, technology assessment, socio-economic assessment and safety assessment. This is possible through the generation of additional financial resources, providing political support for biotechnology, promoting basic and product-oriented research and participation in science-industry consortia.

Public Awareness

An opinion survey conducted in 1989 in both developing and developed countries showed a widespread concern about environmental deterioration, and it was felt that more should be done to reverse the present trend even if this means foregoing some material gains. There has been a general perception on the quality of the environment throughout the world. In the majority of these countries, the public believe that the environment had deriorated over the last one to two decades and it will still become worse during the coming few decades. People have shown great concern about the pollution of drinking-water, lakes, rivers and the sea, as well as the loss of agricultural land, the disappearance of trees and forests and desertification. Air pollution, radioactivity from nuclear reactors and pollution caused by chemicals have also been major concerns to the public.

It is widely believed that environ-

mental degradation could be contained or reversed if governments work together and people are made aware of all the facts. In some countries political survival now depends on the public opinion on environmental matters. The environment has become a global political issue which cannot be neglected at any stage.

New Technologies

A number of new technologies have developed in many areas of biology. Some of the techniques useful in the management of biotechnologies are briefly mentioned below.

Restriction Fragment Length Polymorphism (RFLP)

Techniques such as isoenzyme analysis or restriction fragment length polymorphism have been utilized for crop improvement. In the last few years the application of RFLP analysis to problems in plant genetics and breeding is being exploited.

Polymerase Chain Reaction (PCR)

Recently polymerase chain reaction has become one of the most enabling technologies. It is an *in-vitro* method for producing large amounts of specific DNA fragments of defined length and sequence from small amounts of a complex template. Since PCR can amplify a DNA target over a million times, it can be used to detect molecules that are present usually at low concentrations in a biological sample. DNA target fractions can be amplified which are detectable by a probe.

PCR, with its capacity of synthesizing millions of copies of a specific target DNA fragment from a complex template, has made possible new approaches to problems in molecular genetics, evolutionary biology, and development. This rapid, sensitive and automated amplification reaction can be combined with simple non-radioactive methods for detecting the amplified target sequences and thus promises to play a crucial role in all DNA-based diagnostics procedure, including diagnosis of cancer and infectious diseases. This technique is widely being used in the area of plant molecular biology.

DNA Finger-printing

Within a species, most sections of the genome show little or no variation between individuals. There is, however, one region of the genome of the human and some other vertebrate species that is genetically unique in every individual (except identical, siblings and clones). This segment of the genome is called satellite DNA, which can be isolated by a cDNA probe and then examined in further detail by RFLP analysis.

Each person's DNA has individual patterns which are a powerful forensic tool and have been used to resolve questions about blood-relatendness between family members. The technique has a great potential in fields of agriculture, animal husbandry and social problems like medico-legal cases (especially disputed parentage), linkage and analysis in disease condition DNA finger-prints are stable and transmitted from generation to generation.

In plants, paternity testing has many potential applications, one of them being the determination of parentage for economically important cultivars of unknown origin. Such information could be of great use in plant breeding work. The versatility and overall information of a finger-printing of plant species being tested are maize, *Cicer arietinum*, *Hordeum vulgare* and *Brassica napus*.

Conclusions

Biotechnology has wide application in several sectors of great economic relevance for both developing and developed countries. Major advances in biotechnology offer immense opportunities of its application for better quality of life and increased productivity. Biotechnology integrated with conventional techniques can ensure food security, better health care and congenial environment. Sustainable developments in relation to environmentally sound management of biotechnology include problems related to environmental monitoring conservations, economic efficiency, preventive protection strategy and the minimization of waste material. Management of biotechnologies also includes substitution of non-renewable resources with renewable resources, global changes in biological diversity and risk assessment. If used with care and appropriate management, and with proper monitoring practices, biotechnology may provide immense benefits to mankind.

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