Biotechnology and its Applications

Applications of Biotechnology in Agriculture

Genetically Engineered Crops

- Genetically engineered crops have desirable genes (as of insect/pest resistance, giving better yield) incorporated in them.
- Genetically modified crops have
- more tolerance to abiotic stresses such as cold, drought, salinity, heat, etc.
- insect/pest resistance
- reduced post-harvest losses
- efficient mineral usage by plants
- enhanced nutritional value (e.g., **Golden rice**, a variety of rice is rich in Vitamin A)

***Bt* Cotton**

- *Bacillus thuringiensis* is a bacterium that produces proteins to kill certain insects such as lepidopterans (armyworm), coleopterans (beetles), and dipterans (flies/ mosquitoes). *B. thuringiensis* produces a protein crystal containing a toxic protein (inactivated state).
- Inactivated toxin $\xrightarrow{\text{alkaline pH}}$ Activated toxin (gut of insect)
- Activated toxin binds to the epithelial cells in the midgut of insect and creates pores that cause lyses and swelling and eventually death of insect.
- This toxin is encoded by a gene called **Cry** in the bacterium. Genes encoded by *Cry IAc* and *Cry II Ab* control cotton bollworms and those encoded by *Cry IAb* control corn borer.
- Cry genes are introduced into the cotton plants to produce *Bt* cotton, which is an insect resistant variety of cotton.

RNA Interference (RNAi)

- RNAi is a method adopted to prevent infestation of roots of tobacco plants by a nematode *Meloidegyne incognitia*.
- In RNAi, a complementary RNA binds to mRNA to form a ds RNA, which cannot translate and hence, its expression is blocked (Silencing).

- This complementary mRNA may come from
- infection by RNA viruses
- transposons (mobile genetic elements)
- RNAi exists naturally in eukaryotes as a method of cellular defence.
- Nematode specific genes (DNA) were introduced in the host plant.
- The introduced DNA forms both sense and anti-sense RNA.
- Two strands being complementary to each other bend and form ds RNA, leading to RNAi.
- mRNA of nematode is silenced and the parasite cannot survive in the transgenic host.

Applications of Biotechnology in Medicine

Recombinant Therapeutics

- With the help of RDT, mass production of efficient therapeutic drugs can be accomplished.
- These are safe and do not induce unwanted immunological response.

Genetically Engineered Insulin

- Insulin is in great demand due to increase in number of patients with adult onset diabetes.
- Insulin extracted from animal source (example, slaughtered cattle and pigs) induce allergy in humans.
- Insulin as a pro-hormone consists of 3 peptide chains – A, B, and C.
- Pro-hormone insulin $\xrightarrow{\text{removal of C peptide}}$ Mature insulin
- Mature insulin consists of only two peptide chains – A and B. Both these chains were separately isolated and introduced in plasmids of *E. coli* to produce insulin chains.
- Separately produced chains A and B were extracted and combined by creating a disulphide bond to form mature human insulin.

Gene Therapy

- Gene therapy is an attempt to deal with genetic or congenital diseases.

- This aims at correction of a genetic defect by delivery of a normal gene into an individual or embryo to take over or compensate the function for a non-functional gene.
- The first disease to have a gene therapy is ADA (Adenosine deaminase) deficiency. In this, the gene coding for enzyme ADA gets deleted leading to deficiency of ADA and problems in immune system.
- ADA deficiency can also be treated with:
- Bone marrow transplantation
- Enzyme replacement therapy
- Gene therapy for ADA deficiency:
- Lymphocytes isolated from patient's blood are cultured in-vitro.
- Functional ADA cDNA are then introduced into the cultured lymphocytes.
- These lymphocytes are returned back to the patient's body.
- Lymphocytes are not immortal. Therefore, repeated infusion of genetically engineered lymphocytes is required.
- Permanent cure – Introduction of gene isolated from bone marrow cells producing ADA into cells at early embryonic stages

Molecular Diagnosis

- Recombinant DNA technologies, PCR, ELISA (enzyme linked immuno sorbent assay) are some of the technologies of molecular diagnosis.
- Early diagnosis of bacteria and virus in body, when the concentration is extremely low, can be done by PCR since it amplifies the DNA several folds.
- PCR is used to detect HIV virus in suspected AIDS patients and mutations in genes in suspected cancer patients.
- ELISA is based on antigen-antibody interactions. In the presence of an antigen, the antibody produced against it can be detected.
- Hybridisation with a radioactive probe – In this approach, gene is hybridized with a radioactive probe and autoradiography is used for detection. The regions where mutation is present in the gene will not appear in the photographic film since probe will not be able to bind with that part.

Transgenic Animals & Biopiracy

Transgenic Animals

- Animals that have their DNA manipulated to possess or express an extra gene are called transgenic animals.
- Till date, transgenic rats, rabbits, pigs, sheep, cows, and fish have been produced.

Reasons for Producing Transgenic Animals

- **Study of normal physiology**
- Transgenic animals serve as models to study genetics, regulation and down regulation of genes, and their corresponding effects on physiology.
- They give information about the biological role of a particular factor in the body.
- **Study of diseases**
- They act as models to study genetic basis of diseases.
- These studies aid in finding possible treatments of diseases.
- Transgenic models exist of various human diseases such as cancer, cystic fibrosis, rheumatoid arthritis, Alzheimer's, etc.
- **Biological products**
- Treatment of diseases often requires certain products that are expensive to make.
- Transgenic animals can be produced that have genes, coding for that particular product.
- Example – Human protein α-1-antitrypsim used to treat emphysema is isolated by this method.
- In 1997, first transgenic cow Rosie produced human protein-enriched milk, which contained α-lactalbumin and was nutritionally more suitable for human babies.
- **Vaccine safety tests**
- Transgenic mice are used to test vaccines for their safety before they are used for humans.
- Example – Transgenic mice are used to check polio vaccines.
- **Chemical safety testing**
- Transgenic animals contain genes that make them more sensitive to toxic substances than non-transgenic.

- Toxicity testing in such animals helps us to obtain results in less time.

Ethical Issues Associated with Transgenic Animals

- Indian government has set up an organization GEAC (Genetic Engineering Approval Committee), which makes decisions regarding validity of GM research and its use for public utility.
- Modification which may result in the loss of biological significance of animals cannot go beyond regulation.
- Unpredictable results may be observed, if these organisms are introduced in natural ecosystem.
- Patents for transgenic varieties also create problems as many indigenous varieties are claimed by multinational companies as their own inventions.
- For example – A new variety of Basmati was claimed by an American company through patenting. This new variety was actually derived by Indian farmers by crossing Indian Basmati with semi-dwarf varieties.
- Similarly Neem and turmeric, which have been used for ages in Indian medicines, are also matters of dispute for patent rights.

Biopiracy

- Use of bio-resources by MNCs and other organisations without proper authorisation from countries and people concerned without compensatory payment
- Industrialized and developed nations are economically rich, but poor in biodiversity while opposite prevails for developing nations. Therefore, developed countries exploit traditional knowledge and resources of poor countries for commercialisation.
- This is a matter of injustice since inadequate compensation and benefit sharing is given to poor countries in return. Therefore, steps should be taken by developing countries to prevent this exploitation.
- The Indian parliament has recently introduced second amendment of Indian patents bill to deal with these issues.

Patents

A patent is an exclusive right which is granted for an invention, which could be a product or a process that provides, in general, a new way of doing something, or offers a new technical solution to a problem.

Patents are awarded to those processes or products which can satisfy the three criterias - novelty, non-obviousness, and utility.

Controversies in India regarding patent and biopiracy:

Turmeric - The US Patent Office in 1995, granted to the University of Mississippi Medical Center a patent for "Use of Turmeric in Wound Healing." So whats the big deal about it? Lets understand it with an example, if an Indian in America sprinkles turmeric powder – just as her ancestors in India have done for centuries – on her child's scrape, she would in fact be infringing US patent laws and would be open to prosecution.
This patent was challenged by Dr. R A Mashelkar, an Indian scientist which resulted in the successful revocation of the patent.

Neem - In 1996, the European Patent Office, Munich granted the firm of W.R. Grace & Co. a patent for the 'fungicidal uses of neem oil'.
This patent was challenged by Vandana Shiva and Ajay Phadke, who had researched neem in India. Legal action by the Indian government followed, with the patent eventually being overturned in 2005.

Basmati rice - In September 1997, Rice Tec, a Texas company won a patent on "basmati rice lines and grains." The patent secured lines of basmati and basmati-like rice and ways of selecting that rice for breeding. There were allegations of biopiracy on Rice Tec. India took this matter to the international level and voluntarily, and due to review decisions by the United States patent Office, Rice Tec lost most of the claims of the patent.