CHAPTER – 12 : BIOTECHNOLOGY AND ITS APPLICATIONS

The applications of biotechnology include therapeutics, diagnostics and genetically modified crops for agriculture, processed food, bioremediation, waste treatment, and energy production.

Three critical research areas of biotechnology are;

- Providing the best catalyst in the form of improved organism usually a microbe or pure enzyme.
- Creating optimal conditions through engineering for a catalyst to act, and
- Downstream processing technologies to purify the protein / organic compound.

Biotechnological Applications in Agriculture:

The three options that can be thought for increasing food production are,

- Agro-chemical based agriculture
- Organic agriculture; and
- Genetically engineered crop-based agriculture.

The Green Revolution has succeeded in tripling the food supply but yet it was not enough to feed the growing human population. Scientists have decided that use of genetically modified crops is a possible solution.

Plants, bacteria, fungi and animals whose genes have been altered by manipulation are called Genetically Modified Organisms (GMO). Genetic modification has;

- Made crops more tolerant to abiotic stresses
- Reduced reliance on chemical pesticides
- Helped to reduce post harvest losses
- Increased efficiency of mineral usage by plants
- Enhanced nutritional value of food, eg., Vitamin 'A' enriched rice.

Bt Cotton:

Some strains of *Bacillus thuringiensis* produce a toxic insecticidal protein. The Bt toxin protein exist as inactive protoxins but once an insect ingest the inactive toxin, it is converted into an active form of toxin due to the alkaline pH of the gut which solubilise

the crystals. The activated toxin binds to the surface of midgut epithelial cells and creates pores that cause cell swelling and lysis and eventually cause death of the insect.

Bt toxin genes were isolated from *B. thuringiensis* and incorporated into the several crop plants such as cotton. The toxin is coded by a gene named '*cry*'. There are a number of them, for example, the proteins encoded by the genes *cryIAc* and *cryIIAb* control bollworms and *cryIAb* controls corn borer.

Pest Resistant Plants:

A nematode *Meloidegyne incognitia* infects the roots of tobacco plants and causes a great reduction in yield. A novel strategy was adopted to prevent this infestation which was based on the process of RNA interference (RNAi). This method involves silencing of a specific mRNA due to a complementary dsRNA molecule that binds to and prevents translation of the mRNA (silencing).

Using *Agrobacterium* vectors, nematode-specific genes were introduced into the host plant. The introduction of DNA was such that it produced both sense and anti-sense RNA in the host cells. These two RNA's being complementary to each other formed a double stranded (ds DNA) that initiated RNAi and thus, silenced the specific mRNA of the nematode. The consequence was that the parasite could not survive in a transgenic host expressing specific interfering RNA. The transgenic plant therefore got itself protected from the parasite.

Biotechnological Application in Medicine:

The rDNA technological processes have made immense impact in the area of healthcare by enabling mass production of safe and more effective therapeutic drugs. At present, about 30 recombinant therapeutics have been approved for human use the world over. In India, 12 of these are presently being marketed.

Genetically Engineered Insulin:

Insulin consists of two short polypeptide chains; chain A and chain B, that are linked together by disulphide bridges. In mammals, including humans, insulin is synthesized as a prohormone, which contains an extra stretch called the C peptide. This C peptide is not present in the mature insulin and is removed during maturation into insulin.

In 1983, Eli Lilly an American company prepared two DNA sequences corresponding to A and B, chains of human insulin and introduced hem in plasmids of *E.coli* to produce insulin chains. Chains A and B were produced separately, extracted and combined by creating disulfide bonds to form human insulin.

Gene Therapy:

Gene therapy is a collection of methods that allows correction of a gene defect that has been diagnosed in a child / embryo. Correction of a genetic defect involves delivery of a normal gene into the individual or embryo to take over the function of and compensate for the non-functional gene.

The first clinical genet therapy was given in 1990 to a 4-year old girl with adenosine deaminase (ADA) deficiency. This enzyme is crucial for the immune system to function.

As a first step towards gene therapy, lymphocytes from the blood of the patient are grown in a culture outside the body. A functional ADA cDNA is then introduced into these lymphocytes, which are subsequently returned to the patient. However, if the gene isolate from marrow cells producing ADA is introduced into cells at early embryonic stages, it could be a permanent cure.

Molecular Diagnosis:

Recombinant DNA technology, Polymerase Chain Reaction (PCR) and Enzyme Linked Immuno-sorbent Assay (ELISA) are some of the techniques that serve the purpose of early diagnosis.

PCR:

A very low concentration of a bacteria or virus can be detected by amplification of their nucleic acid by PCR. PCR is now routinely used to detect HIV in suspected AIDS patients. It is being used to detect mutations in genes in suspected cancer patients too.

ELISA:

It is based on the principle of antigen-antibody interaction. Infection by pathogen can be detected by presence of antigens or by detecting the antibodies synthesized against the pathogen.

Transgenic Animals:

Animals that have had their DNA manipulated to possess and express an extra (foreign) gene are known as Transgenic Animals.

Reasons for the production of transgenic animals:

a) ***Normal physiology and development***: Transgenic animals can be specifically designed to allow the study of how genes are regulated and how they affect the normal functions of the body and its development.

b) ***Study of disease:*** Many transgenic animals are designed to increase our understanding of how genes contribute to the development of disease, so that investigation of new treatments for diseases is made possible.

c) ***Biological products:*** Transgenic animals that produce useful biological products can be created by the introduction of the portion of DNA (gene) which codes for a particular product such as human protein (alpha – 1-antitrypsin) used to treat emphysema. The first transgenic cow, Rosie, produced human protein-enriched milk (alpha-lactalbumin - 2.4 gm / litre).

d) ***Vaccine safety:*** Transgenic mice are being developed for use in testing the safety of vaccines before they are used on humans (polio vaccine).

e) ***Chemical safety testing:*** Transgenic animals are made that carry genes which make them more sensitive to toxic substances than non-transgenic animals. They are then exposed to the toxic substances and the effects studied.

Ethical Issues:

The Indian Government has set up organizations such as GEAC (Genetic Engineering Approval Committee), which will make decisions regarding the validity of GM research and the safety of introducing GM-organisms for public services.

Biopatent:

A patent is the right granted by a government to an inventor to prevent others from making commercial use of his invention. Now, patents are granted for biological entities and for products derived from biological resources.

Biopiracy:

It is the term used to refer to the use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned without compensatory payment.

In 1997, an American company got patent rights on Basmati rice through the US Patent and Trademark Office. This allowed the company to sell a 'new variety of Basmati, in the US and abroad. This 'new' variety of Basmati had actually been derived from Indian farmer's varieties. Indian Basmati was crossed with semi-dwarf varieties and claimed as an invention or a novelty.

Several attempts have also been made to patent uses, products and processes based on Indian traditional herbal medicines, e.g., turmeric and neem.

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