“Applications of Plant Biotechnology”

Content

Introduction

- Biotechnology is the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services.

- Plant biotechnology can be defined as the introduction of desirable traits into plants through genetic modification.

Application of Plant Biotechnology

- **Abiotic Stress Tolerance Plants**
- **Biotic Stress Tolerance Plants**
- **Genetically Modified Foods (GM foods)**
- **Pharmaceuticals**
- **Industrial Products**
- **Others**

Abiotic Stress Tolerance Plants

Abiotic Stress

- Salt Tolerance
  - Manitol gene

  Manitol possibly help the cells to lower their osmotic potential and to draw water from the outside medium. By introducing manitol-1-phosphate dehydrogenease gene (mt1D) isolated from *E. coli* showed over-expression of manitol in tobacco plants

  - LEA protein

  It has been suggested that LEA(Late Embryogenesis Abundant) type proteins act as water binding molecules, in ion sequestration and membrane stabilization.

Cont.

- Trehalose

The stabilization of biological structure and enhances the tolerance of organisms to abiotic stress transformed tobacco plants with trehalosesynthetase (Tsase) gene.

- H+-pyrophosphatase (H+-Ppase) gene.

Over expression of H+-Ppase causes the accumulation of Na+ in vacuoles instead of in the cytoplasm and avoids the toxicity of excess Na+ in plant cells.

Cont.

Drought Tolerence

- Trihelose biosynthesis

The gene TPS1 found in yeast encodes for *trehalose*-6-*phosphate synthetase* and is involved in biosynthesis of trehalose. The transgenic tobacco plants containing the yeast TPS1 gene exhibited multiple alteration and improved drought tolerance

- LEA protein

Gene HVA1 encodes for a group of three LEA proteins which get accumulated in vegetative organs during drought condition.

Cont.

- Fructan synthesis

The bacterial gene sacB found in *Bacillus subtilis* encodes for levan sucrase, which takes part in fructan synthesis. Fructan promotes the process of root branching, thus increasing root surface and water uptake.

- Wax production

The gene designated WXP1, is able to activate wax production and confer drought tolerance in alfalfa.

Biotic Stress Tolerance Plants

Biotic Stress Resistance Plants

- Viral resistance
- Bacterial resistance
- Fungal resistance
- Insect resistance
- Herbicide resistance

Virus resistance

- Cross-Protection

Several mechanisms have been proposed to explain possible hypothesis of cross protection. They are:

- Replication of inducer virus (mild strain) prevents availability of host cell component to challenge virus and prevent its replication.
- Coat protein is produced by inducer virus encapsulate the RNA of challenger, thereby preventing its replication.

Cont.

- Satellite RNA Mediated Resistance

Satellites are replicated in cells infected with the particular virus. The transgenic plant which express full-length satellite tobacco ringspot RNA virus (STobRV) and confirmed excellent resistance when infected with TobRV.

- Ribozyme Mediated Resistance

Expression of ribozyme in transgenic plants can targeted for the destruction of specific RNA have been demonstrated using protoplast culture.

Cont.

- Artificial MicroRNAs Mediated Resistance

Artificial miRNAs target the genomic RNAs of plant viruses and destroy them within plant system

Fungal Resistance Crop

Chitinase and Glucanase

- Chitinase and glucanase catalyze the hydrolysis of two major structural components chitin and glucan, respectively, of the cell wall of many fungi
- Chitinase genes have been identified from plants and micro-organisms and are broadly known as the PR-3 class of proteins.

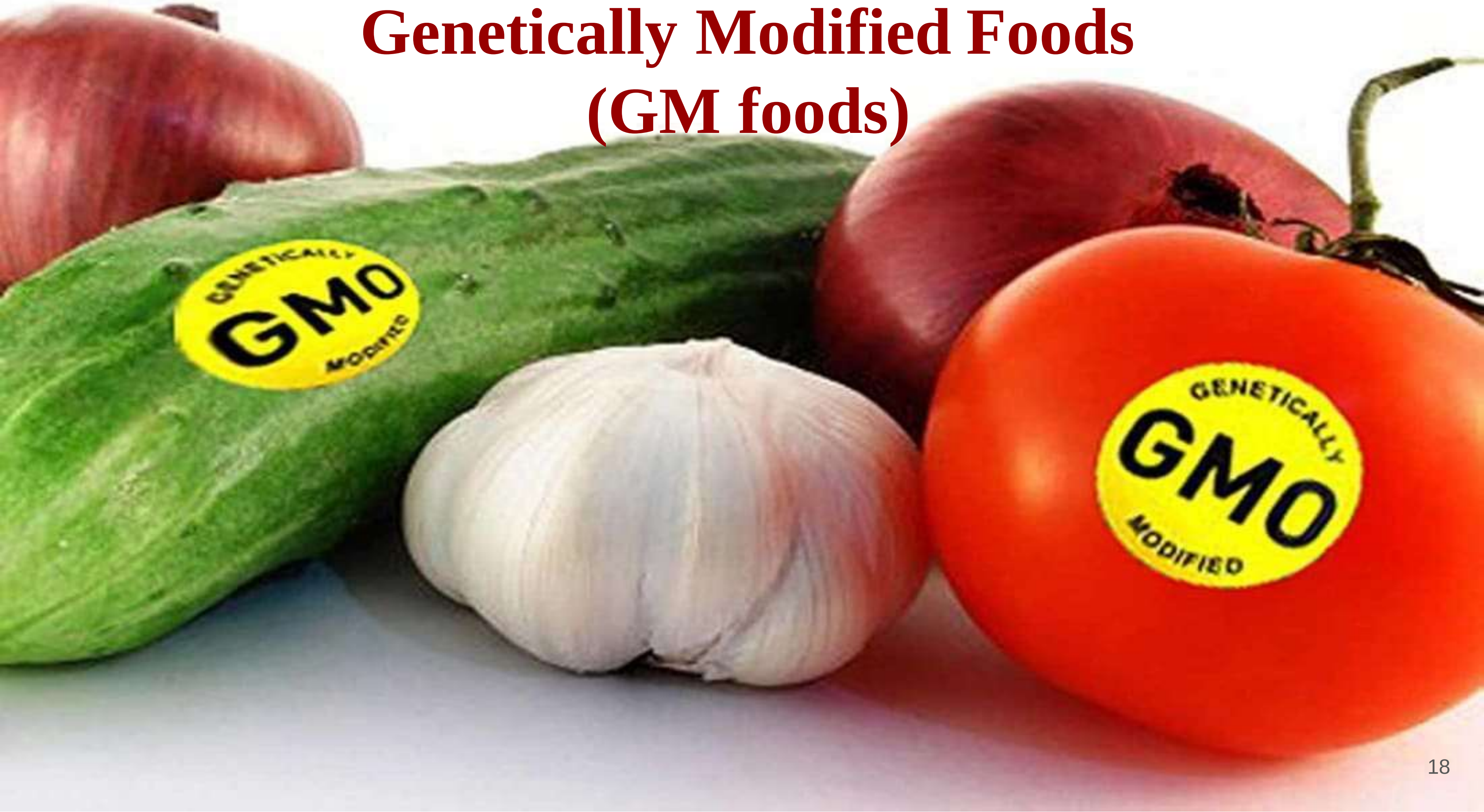
Insect resistance

- The genes from *Bacillus thuringiensis* have been extensively used in this context
- The modification of Bt genes for better expression in plants was an important step towards obtaining insect resistance in plants
- Proteinase inhibitors (PIs) have been reported to show significant inhibitory activity against insect digestive enzymes.

Herbicide resistance

- Inhibit uptake of the herbicide.
- Overproduce the herbicide-sensitive target protein.
- Introduce a bacterial or fungal gene that produces a protein that is not sensitive to the herbicide.
- Reduce the ability of a herbicide-sensitive target protein to bind to a herbicide.
- Endow plants with the capability to metabolically inactivate the herbicide.

Genetically Modified Foods
(GM foods)



Genetically Modified Foods (GM foods)

- Genetically modified foods (GM foods) are foods produced from organisms that have had changes introduced into their DNA using the methods of genetic engineering.
- Commercial sale of genetically modified foods began in 1994, when Calgene first marketed its unsuccessful Flavr Savr delayed ripening tomato.
- Most food modifications have primarily focused on cash crops in high demand by farmers such as soybean, corn and cotton.

Cont.

- Genetically modified crops have been engineered for resistance to pathogens and herbicides and for better nutrient profiles.

Figure: Golden Rice.

Source: gmo.geneticliteracyproject.org

Figure: Bt Cotton.

Source: biologydecoded.com

List of Important Crops Genetically Modified with Nutritionally Improved Traits

Cereal Crops

- Rice
- Wheat
- Maize

Oilseed

- Soybeans
- Lupin
- Sorghum

Narcotics

- Coffee

Cont.

Tuber

- Potato
- Sweet potato
- Cassava
- Beet

Fruit and Vegetables

- Tomato

Other crops

- Alfalfa
- Cotton

Benefits

- Insect Resistance
- Disease Resistance
- Herbicide Resistance
- Nutritional and Other Enhancements

Health and Safety

- There is a scientific consensus that currently available food derived from GM crops poses no greater risk to human health than conventional food, but that each GM food needs to be tested on a case-by-case basis before introduction.
- Nonetheless, members of the public are much less likely than scientists to perceive GM foods as safe.

Pharmaceuticals

Edible Vaccine

- Edible vaccines involves the process of incorporating the selected desired genes into plants and then enabling these altered plants to produce the encoded proteins.

- Edible vaccines offer cost-effective, easily administrable, storable and widely acceptable as bio friendly particularly in developing countries.

Plants used for edible vaccine

- Tobacco
- Potato
- Banana
- Tomato
- Rice
- Soybean
- Carrot
- Peanut
- Wheat
- Corn

Advantages of Edible Vaccines

- Mode of action for immunization, as they do not require subsidiary elements to stimulate immune response.
- Do not need sophisticated equipments and machines as they could be easily grown on rich soils.
- Widely accepted as they are orally administered unlike traditional vaccines that are injectable.

Limitations of Edible Vaccines

- Individual may develop immune tolerance to the particular vaccine protein.
- Dosage required varies from generation to generation and, plant to plant.
- Are dependent on plant stability as certain foods cannot be eaten raw
- Edible vaccines get microbial infestation.

Production of Phytochemicals

- Phytochemicals are chemical compounds produced by plants.

- Produced by plants through primary or secondary metabolism

- They generally have biological activity in the plant host and play a role in plant growth or defense against competitors, pathogens, or predators.

- The presence of valuable metabolites in plants has stimulated interest on the part of industry in the fields of phytochemicals by using biotechnological technique.

Industrial Products

Bioplastics

A **bioplastic** is a substance made from **organic biomass sources**, unlike conventional plastics.

Polyhydroxyalkanoate is one of the major component of bioplastic production.

The cost of PHAs could be considerably reduced if they were produced on an agricultural scale in transgenic crops.

Figure: Symbol of Bioplastic

Biofuel

Biofuel, any fuel that is derived from **biomass**—that is, plant or algae material or animal waste.

Now-a-days transgenic plants are used for biofuel production.

Figure: Life cycle of Biofuel.

Oleochemicals

About 20% of the total output of plant oils is used as a feedstock for the production of oleochemicals.

The first transgenic crop with a modified output trait to be approved for commercial cultivation was a **lauric oil** (12-carbon) rapeseed variety grown in 1995.

Figure: Lauric oil

Starches

World needs a large amounts of starch every year

Starch grains in plants contain two principal polysaccharides, amylose and amylopectin.

Amflora is a genetically modified starch potato.

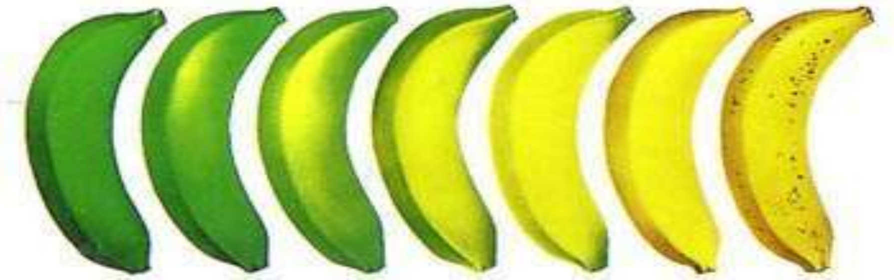
Figure: Genetically modified starch potatoes

Fruit Ripening

- Process by which fruits attain their desirable flavour, quality, color, palatable nature and other textural properties.

  Based on ripening fruits are

  i. Climacteric
  ii. Non-climacteric fruits.



Flower wilting

- ✓ Natural senescence process of flower
- ✓ One of the great problem in flower marketing
- ✓ Causes million dollar loss worldwide.

Control of wilting by GE

ACC oxidase cDNA fragment in Torenia

- ✓ 2.0 days to 4.4 days

Shelf Life Enhancement

- ✓ Transgenic ornamental plants have potential to enhance leaf and flower longevity
- ✓ Autocatalytic ethylene synthesis
- ✓ Treated with different kinds of chemicals
- ✓ Carnation plants exhibit delayed petal senescence.

Flower Pigmentation

- ✓ Modification of flower color
- ✓ Market value is around $150 billion.
- ✓ The main areas of flower production are- USA, Europe, Israel, Ecuador, Morocco etc.

Flower Pigmentation

Three groups of pigments

- Flavonoids
- Carotenoids
- Betalains

Chlorophylls can also flower pigments.

Application of Plant Biotechnology in Nitrogen Fixation

- Within the constraints of the climate and season, good legume management to maximize productivity will benefit N_2 fixation. Examples of legume management including optimizing nutrient inputs (e.g. P), reducing acidity with lime, managing weeds, disease and insects.

Cont.

- Plants that contribute to nitrogen fixation include those of the legume family – *Fabaceae* –.
- They contain symbiotic bacteria called rhizobia within nodules in their root systems, producing nitrogen compounds that help the plant to grow and compete with other plants.

Nutritional Quality Improve of Food

From a consumer perspective, the focus on value-added traits, especially improved nutrition, is of greatest interest.

- ❖ **Protein**
- ❖ **Carbohydrate**
- ❖ **Fiber**
- ❖ **Lipids**
- ❖ **Vitamins and Minerals**

Conclusion

- Plant biotechnology has huge impact in modern world.
- It will play great role to deal with upcoming population explosion.
- It helps us to discover the undiscovered