1. Genetically Modified (GM) Crops

1.1. What are GM Crops?

- Plants in which one or more **genes from any other plant, animal or micro-organism have been incorporated** in their genome employing techniques of genetic engineering are referred to as transgenic plants.
- In the case of crops, transgenic plants are termed genetically modified crops or GM crops. The food prepared from GM crops is called GM food.
- The **first GM crop, an antibiotic-resistant tobacco plant**, was produced in 1982. China was the first country to commercialise transgenic plants, introducing a virus-resistant tobacco in 1992.
- Transgenic plants find use in agriculture, industry, medicine and environmental cleanup.

1.2. Features of GM Crops

Potential amenable characters which can be introduced through gene transfer to crop plants are:

- Disease resistance
- Delayed ripening of fruits
- Herbicide tolerance
- Insect pest resistance
- Drought and stress tolerance
- Production of foreign proteins
- Expression of high value products in seeds
- Efficient photosynthesis
- Production of secondary metabolites
- Improvement in vitamin A content and improvement in iron content in crops like rice
- Production of transgenics that can be used as edible vaccines
- Improvement in the content and composition (fatty acid composition) of edible oils in rapeseeds and other oilseed crops
- Improvement in the architecture, colour, fragrance and vase life of flowers of commercial value.

1.3. Traits Modified in GM Crops

Herbicide Tolerance

- The most common herbicide tolerant (HT) crops are known as Roundup Ready®, meaning they are tolerant to glyphosate (the active ingredient in Roundup herbicide).
- Roundup Ready® crops have been engineered to produce a resistant form of the enzyme, so they remain healthy even after being sprayed with glyphosate.

Insect Resistance

- Insect-resistant crops contain genes from the soil bacterium *Bacillus thuringiensis* (*Bt*).
- *Bt* produces a group of proteins known as the *Bt* toxin, which are toxic for certain insects, but do not harm beneficial insects or other animals.
- *Bt* is used as an insecticide spray in organic farming. Genes for several *Bt* toxins have been introduced into many crops by GM.

Virus Resistance

- Genetic modification has been used to resurrect the papaya industry of Hawaii as papaya ringspot virus almost destroyed its plantations in the 1990s.
- There are no known papaya varieties with natural resistance to this virus but by adding a gene to the papaya from the virus itself, resistant papaya strains were created.

1.4. Modes of Gene Transfer in Plants

Methods for plant transformation mostly utilise:

1. Direct gene transfer methods
2. *Agrobacterium* mediated transformation
3. Virus mediated gene transfer
4. Floral dip method

Of the above methods, *Agrobacterium* mediated transformation and Particle bombardment (biolistics) are the most important and most effective direct gene transfer method in regular use.

***Agrobacterium* based gene transfer**

- *Agrobacterium* is a **genus of soil borne Gram-negative bacteria** that uses horizontal gene transfer to cause tumours in plants.
- *Agrobacterium tumefaciens* is the most commonly studied species in this genus. *A. tumefaciens* causes **crown-gall disease in plants.**
- *Agrobacterium* is unique for its **ability to transfer DNA between itself and plants** (it can transfer T-DNA part of Ti plasmid to the plant), and for this reason it has become an important tool for plant improvement by genetic engineering.
- It is also called **nature's genetic engineer.** The Agrobacterium method is explained in Figure.1.

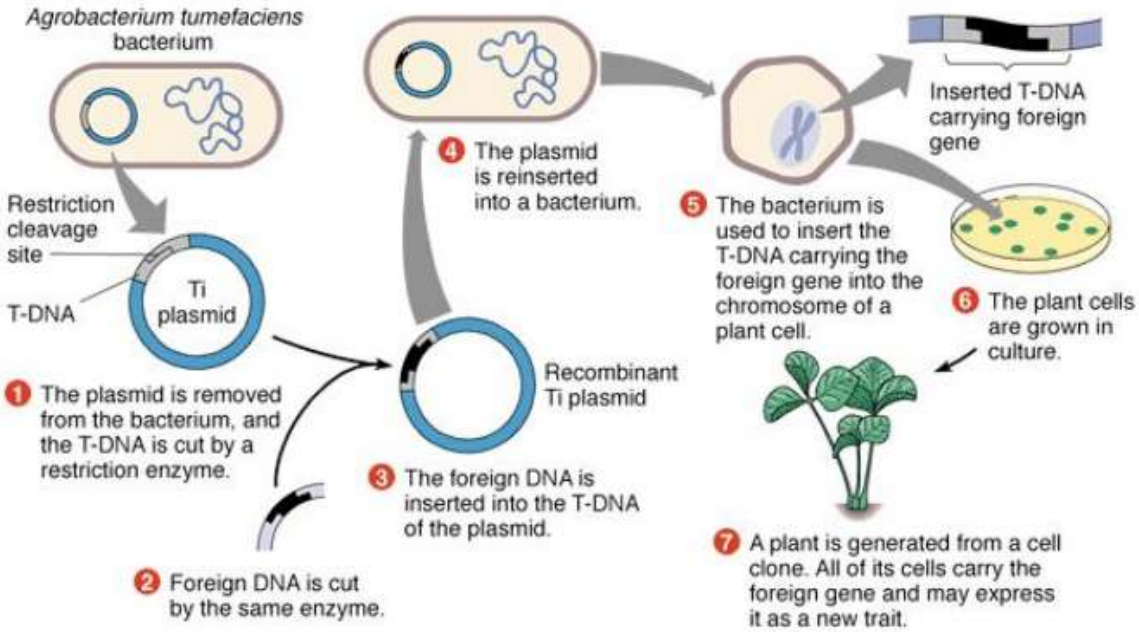

Figure.1. Agrobacterium based gene transfer method

- *Agrobacterium* does not usually infect monocot plant species, but is very effective for dicot species. *Agrobacterium* is listed as being the original source of genetic material that was transferred to these food plants:

- Soybean, Cotton, Sugar Beet, Alfalfa, Rapeseed Oil (Canola), Creeping bentgrass (for animal feed), Potato, Tobacco, Tomato and Brinjal.

Particle bombardment (biolistics)

- To genetically transform cereal crops such as rice, most varieties of wheat etc, biolistics is the most important and most effective direct gene transfer method.
- In this technique, **tungsten or gold particles are coated with the DNA** that is to be used to transform the plant tissue.
- The particles are **propelled at high speed into the target plant material,** where the DNA is released within the cell and can integrate into the genome.

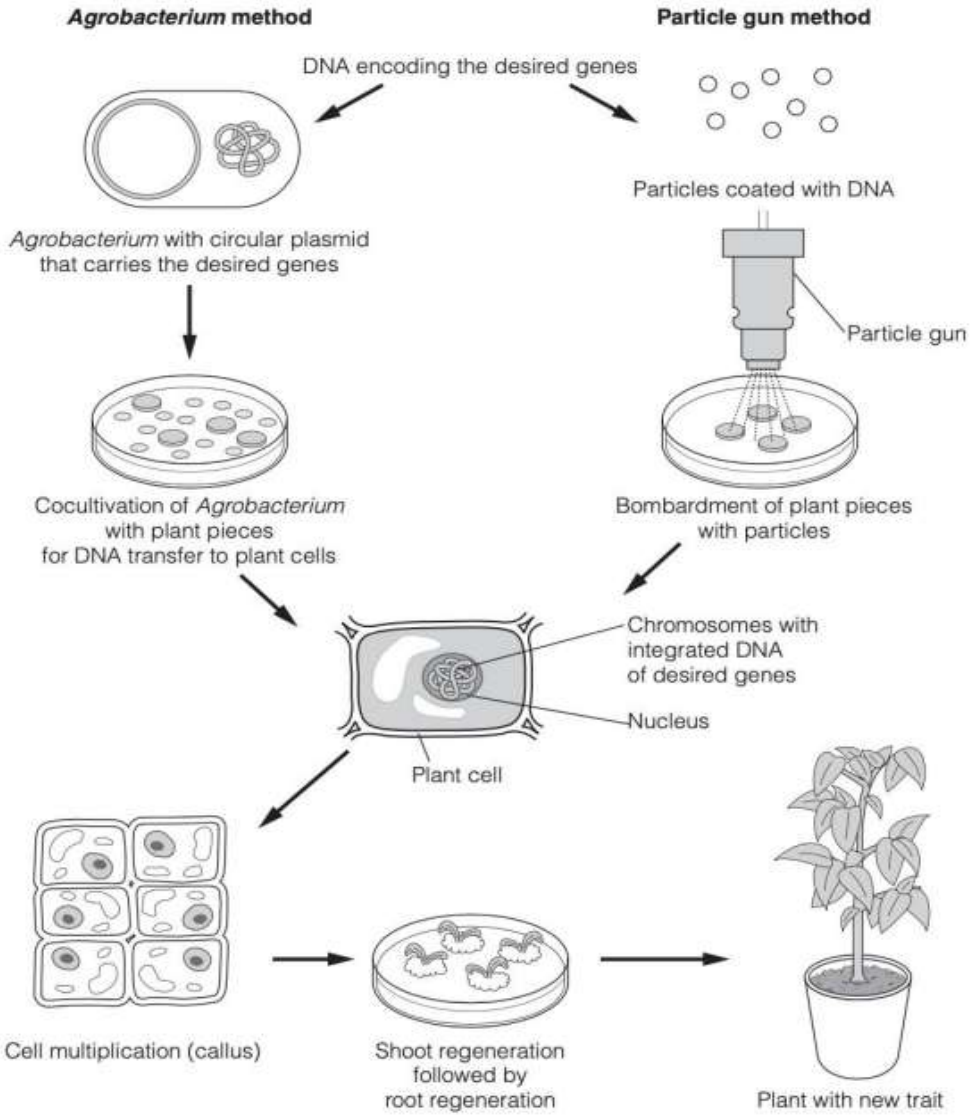

Figure.2. Plant material transformed by an *Agrobacterium* based system and by DNA from particle gun

1.5. Applications of Genetically Engineered Crops

Goal	Use	Typical Method	Examples of Crops Transformed

Herbicide Tolerance	Use of herbicides post emergence of seedlings at lower doses than required before seedling emergence	Introduce bacterial gene for enzyme which degrades the herbicide or which bypasses the point of plant metabolism inhibited	Soybean, canola, corn and cotton
Insect Resistance	Reduce losses without pesticide spraying	Insertion of gene from the bacterium *Bacillus thuringiensis* gives resistance to a range of insect pests	Corn (against European corn borer); cotton (against bollworm); potato (against Colorado beetle)
Post-harvest quality	Increasing shelf-life and reduces losses in transport and harvest	Modified activity of polygalacturonase or other ripening enzymes	Tomato
Virus resistance	Reduced losses due to viral diseases	Insertion of viral coat protein gene into plant	Tobacco (tobacco mosaic virus); potato (potato viruses X and Y)

1.6. Near future possibilities of genetically engineered crops

Goal	Application
Salinity tolerance	Increased crop yield in areas affected by salinity (e.g. in long-term irrigation)
Drought tolerance	Increased crop yield in marginal, semi-arid zones
Waterlogging tolerance	Improved survival in temporary flooding
Enhanced flavour, storage and properties	Improved consumer acceptance; decreased losses; decreased energy inputs to processing or storage; enhanced product value or usefulness
Enhanced amino acid content	Dietary improvement and health
Antibody and pharmaceutical production	Less energy input and cost than use of animal cell culture
Improved disease resistance	Reduced pesticide inputs; increased yields mean population can be fed using smaller land area

2. Areas of concern

There are several areas of concern regulating the use of genetically modified foods. This includes toxicity, allergenicity, cariogenicity, food intolerance and nutritional value. The important issues of concern are as follows:

- **Unnecessary interference** with biological states or processes that have naturally evolved over long periods of time.
- **Limitations of modern science** to fully comprehend all of the potential negative ramifications of genetic manipulation.
- The **safety concerns** of GMOs in the food chain, with issues such as the possibilities that GMOs could introduce new allergens into foods, or contribute to the spread of antibiotic resistance.
- Conventionally-bred crop plants can be cross-pollinated (bred) from the pollen of modified plants.
- GMOs, being better adapted and sometimes more stress and disease tolerant, can grow in a community as an **invasive species** and thus threaten the diversity of the ecosystem.
- Promotion of **unsustainable practices** such as overuse of herbicide, which has been taking place after development of herbicide-tolerant plants (which can withstand the overspray of herbicides).

Additionally, various arguments against herbicide-tolerant transgenics in crop plants have come up lately:

- Use of herbicide-tolerant transgenic crops can lead to **transfer of herbicide-tolerant genes** to sexually compatible wild relatives or weeds, which can be a major potential threat to the environment.
- Transgenic crops **can create "superweeds".**
- It would actually **increase the dependence** on a few herbicides rather than reducing herbicide usage.
- It may increase the **problem of weed control** if weeds develop resistance to such herbicides through gene flow from transgenic crops.
- Herbicide tolerance is being sought not only for environmentally comparatively acceptable herbicides but also for older, more toxic and persistent products.
- Non-chemical means of weed control, such as crop rotation, dense plantings, cover cropping, ridge tillage, and others, however labour-intensive for farmers, are preferable than the use of any herbicide at all. Gene flow is the primary risk in releasing transgenic plants.

3. Cultivation of GM Crops in India

3.1. Introduction

- *Bt* cotton is the **only GM crop** that has been **approved for commercial cultivation in 2002** by the Government of India.
- Long term studies were conducted by ICAR on the impact of *Bt* cotton which did not show any adverse effect on soil, microflora and animal health.

- The Parliamentary Standing Committee on Science and Technology, Environment and Forests, submitted a **report on 'Genetically modified crops and its impact on environment'** to Parliament on August 25, 2017.
- The report recommended that GM crops should be introduced in the country only after critical scientific evaluation of its benefit and safety, and also recommended restructuring of the regulatory framework for unbiased assessment of GM crops.

3.2. *Bt* Cotton

- In 2002 approval for the commercial release of *Bt* cotton hybrids/ varieties **resistant to cotton bollworm** was given by the Genetic Engineering Appraisal Committee (GEAC).
- The **Herbicide Tolerant *Bt* (HT*Bt*) cotton** is another variant of *Bt* cotton. This variant adds **another layer of modification,** making the plant resistant to the herbicide glyphosate. However, it has not been approved by regulators.
    - Fears include glyphosate having a carcinogenic effect, as well as the unchecked spread of herbicide resistance to nearby plants through pollination, creating a variety of superweeds.
- Also, *Bt* cotton has little effect on cotton yield, and although it may have led to an initial reduction in insecticide use, this effect is now diminishing due to insecticide-resistance in insect populations.

3.3. *Bt* Brinjal

- *Bt* Brinjal **resistant to brinjal shoot fly** was approved by GEAC in 2009 but due to a **10 years moratorium** imposed on GM crops by the Technical Expert Committee (TEC) appointed by the Supreme Court of India, no further action on commercialization has been taken.
- In 2020, the GEAC has again allowed biosafety research field trials of two new transgenic varieties of indigenously developed *Bt* Brinjal in eight states (during 2020-23).
    - This has been allowed only after taking no-objection certificate (NOC) from states concerned and confirmation of availability of isolated stretch of land for this purpose.
- These indigenous transgenic varieties of brinjal hybrids – namely **Janak and BSS-793, containing *Bt Cry*1Fa1 gene** (Event 142) – have been developed by the National Institute for Plant Biotechnology, ICAR.

3.4. Dhara Mustard Hybrid-11 (DMH-11)

- The GEAC has in 2022 approved the environmental release of Dhara Mustard Hybrid-11 (DMH-11), a genetically-engineered variant of mustard.
- If approved for commercial cultivation it would be the first genetically modified food crop available to Indian farmers.

3.4.1. What is DMH-11?

- DMH-11 is a hybrid variant of mustard developed by researchers at The Centre for Genetic Manipulation of Crop Plants, University of Delhi.
- DMH-11 (where 11 refers to the number of generations after which desirable traits manifest) is a **result of a cross between two varieties: Varuna and Early Heera-2.**
- This cross was done after introducing genes from two soil bacterium called **barnase and barstar.**

- Barnase in Varuna induces a temporary sterility because of which it can't naturally self-pollinate. Barstar in Heera blocks the effect of barnase allowing seeds to be produced. The result is DMH-11 that not only has better yield but is also fertile.

3.4.2. Are hybrid mustard varieties better?

- Trials conducted over three years by the Indian Council of Agricultural Research (ICAR) suggest that DMH-11 has 28% higher yields than its parent Varuna and was 37% better than local varieties.
- DMH-11 signals the proof of success of the barnase-barstar system that can act as a platform technology to develop newer hybrids.
- Having better hybrids is necessary to meet India's rising edible-oil import bill.

3.4.3. Controversy

- Use of genes that are foreign to the species.
- Preparation of mustard hybrids requires the use of another gene, called the bar gene, that makes it tolerant to a herbicide called glufosinate-ammonium.
- GM mustard plants may dissuade bees from pollinating the plant.

3.4.4. What next for GM mustard?

- In 2017 too, GEAC had cleared the environmental release of GM mustard but the process stalled after a case was lodged in the Supreme Court.
- The Ministry of Environment, Forest and Climate Change has not officially supported GM mustard despite the GEAC being a body under it.
- The GEAC go-ahead only allows DMH-11 to be grown in fields under the supervision of the ICAR.
- The crop would be commercially available after "three seasons" now that they can be grown in large quantities for evaluation.

4. Biosafety Aspects

4.1. What is Biosafety?

Biosafety is a broad term and its means 2 things:

- **In general practice:** Biosafety is the safe working practices associated with handling of biological materials, particularly infectious agents.
- **In the context of biological diversity:** Biosafety refers to protecting the native biological diversity from aggressive invasive species including living-modified organisms.

Its main objective is to keep a check on harmful biological agents, toxins, chemicals, and radiation.

4.2. Biosafety Aspects of GM Crops in India

- The Government of India has very strict guidelines to test and evaluate the agronomic value of the GM crops so as to protect the interests of the farmers. These guidelines address all concerns with regard to the safety of GM seeds.
- The regulatory system for GM crops as operative in the Department of Biotechnology, Ministry of Science and Technology and Ministry of Environment and Forests has guidelines to consider the GM crops on a case-by-case basis towards testing.

4.2.1. Genetic Engineering Appraisal Committee (GEAC)

- Genetic Engineering Appraisal Committee (GEAC) has its primary responsibility in the field of ensuring biosafety.

- It works **under the Ministry of Environment, Forests and Climate Change (MoEFCC).**
- The Committee functions as a **Statutory Body** for approval of activities involving large-scale use of hazardous living microorganisms and recombinants in research and industrial production from the environmental angle **as per the provisions of rules 1989.**
- The Committee is responsible for approval of proposals relating to release of genetically engineered organisms and products into the environment including experimental field trials as per the provisions of Rules, 1989.
- The Committee is also responsible for approval of proposals involving the use of living modified organisms (LMOs) falling in the risk category III and above in the manufacture/import of recombinant pharmaceutical products or where the end product of the recombinant pharmaceutical products per se are LMOs.

Main functions of GEAC

- To permit the use of GMOs and products thereof for commercial applications.
- To adopt producers for restriction or prohibition, production, sale, import & use of GMOs both for research and applications under the Environment Protection Act (EPA), 1986.
- To approve for conduct of large scale field trials, evaluation of large scale field trial data and final approval for release of transgenic crops into the environment.
- To authorise large scale production and release of GMOs and products thereof into the environment.
- To authorise agencies or persons to have powers to take punitive actions under the EPA.

4.2.2. Rules 1989

- For facilitating and regulating the research work on GMOs & products thereof at laboratory scale and also in commercial applications, the Government of India notified **" Rules for the Manufacture/Use/Import/Export and Storage of Hazardous Microorganisms, Genetically Engineered Organisms or Cells " in 1989** under the provisions of Environment (Protection) Act, 1986 through the Ministry of Environment & Forests (MoEF). These rules are commonly referred to as ' Rules 1989'.
- These rules are **implemented by MoEFCC, the Department of Biotechnology** (DBT), Ministry of Science and Technology **and the State Governments** through the six competent authorities notified under the Rules which are as follows:
    a. Recombinant DNA Advisory Committee (RDAC)
    b. Institutional Biosafety Committee (IBSC)
    c. Review Committee on Genetic Manipulation (RCGM)
    d. Genetic Engineering Appraisal Committee (GEAC)
    e. State Biotechnology Coordination Committee (SBCC)
    f. District Level Committee (DLC).

Scope of Rules, 1989

- These rules are very broad in scope essentially covering the entire spectrum of activities involving GMOs and products thereof.
- They also apply to any substances, cells, tissues, products, and foodstuffs, etc.
- New gene technologies apart from genetic engineering have also been included.

Mandate of Rules, 1989

- In accordance with Rules, RCGM shall function from the Department of Biotechnology to monitor the safety-related aspect in respect of ongoing research projects or activities involving hazardous microorganisms, GE organisms and cells and products thereof.
- RCGM shall bring out manuals of guidelines specifying procedure for regulatory process with respect to activities involving GE organisms in research use as well as industrial & environmental applications with a view to ensure human health and environmental safety.
- All ongoing research projects involving hazardous microorganisms, GE organisms or cells and products thereof shall be reviewed to ensure that adequate precautions and containment conditions are being met.
- RCGM shall lay down procedures restricting or prohibiting the production, sale, importation and use of such hazardous microorganisms, GE organisms or cells.

4.3. Cartagena Protocol on Biosafety

- Cartagena Protocol on Biosafety is a **legally binding,** international agreement, **supplemental to the Convention on Biological Diversity.**
- The Protocol seeks to protect biological diversity by managing the movements of Live Modified Organisms (LMOs) between countries.
- The objective of the Cartagena Protocol is **to contribute to ensuring an adequate level of protection** in the field of the safe transfer, handling and use of LMOs resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements.
- It was **adopted on 29 January 2000** as a supplementary agreement to the CBD and **entered into force on 11 September 2003.**
- **India is a signatory** to the Cartagena Protocol on Biosafety and ratified it on January 23, 2003.

What does the Biosafety Protocol do?

- It establishes an **Advance Informed Agreement (AIA)** procedure for ensuring that countries are provided with the information necessary to make informed decisions before agreeing to the import of such organisms into their territory.
- It contains the precautionary approach of the Rio Declaration on Environment and Development.
- The Protocol provides for practical requirements that are deemed to contribute to the safe movement of LMOs.
- The Protocol also establishes a **Biosafety Clearing-House (BCH)** to facilitate the exchange of information on living modified organisms and to assist countries in the implementation of the Protocol.