Vol. 3 Issue-9, May 2023 (e-ISSN: 2582-8223)

Genetically Modified Plants: Methods, Steps of Development of GM Plants

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ARTICLE ID: 21

Abstract

Genetically modified (GM) plants are plants that have been altered by inserting DNA from another organism into their genome. This can give them new or improved characteristics, such as resistance to pests, herbicides, or environmental stress. The methods for creating GM plants involve transferring DNA from a donor organism into plant cells, either by using a bacterium that naturally transfers DNA, or by shooting tiny metal particles coated with DNA into the cells. The plant cells that receive the new DNA are then grown into whole plants that produce seeds with the modified genome. GM plants have several advantages, such as increasing crop yields, reducing costs, and enhancing nutritional quality. However, they also have some disadvantages, such as posing potential risks to human health, biodiversity, and the environment. They may also increase antibiotic resistance, create ethical issues, and affect social and economic aspects of agriculture.

Keywords: Genetically Modified Plants, Gene gun method, Bacterium method.

Introduction

Genetically modified plants are the plants whose genomes have been altered by inserting one or more genes from another organism, usually to confer a desirable trait that would not be possible through conventional breeding. For example, some genetically modified plants are resistant to pests, diseases, herbicides, or environmental stress. Genetically modified plants can also be used for scientific research, to create new colours, or to produce vaccines or other useful substances.

There are different methods to create genetically modified plants. One of the most common methods is to use a soil bacterium called Agrobacterium tumefaciens, which can transfer a part of its DNA (called T-DNA) into the plant cells it infects(Chilton et al. 1977).

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The T-DNA can be modified in the laboratory to carry the genes of interest and then introduced into the plant cells using Agrobacterium (Ülkeret al 2008). Another method is to use a gene gun or a microprojectile to shoot tiny particles coated with DNA into plant cells. The DNA can then integrate into the plant genome randomly. Other methods include using viruses, plasmids, or electroporation to deliver DNA into plant cells (Gelvin SB 2003).

Genetically modified plants have potential benefits and risks for human health and the environment. Some of the benefits include increasing crop yield and quality, reducing pesticide use and chemical inputs, enhancing nutritional value and shelf life, and providing new sources of biofuels and bioplastics (Qaim 2010). The WHO reported that the risks include creating new allergens or toxins, transferring genes to non-target organisms or wild relatives, disrupting ecological balance and biodiversity, and affecting social and ethical issues such as food sovereignty and intellectual property rights.

Method for Creating Genetically Modified Plants

Genetically modified (GM) plants are plants that have been engineered to have new or improved traits, such as resistance to pests, diseases, herbicides, or environmental stress. GM plants are produced by introducing specific segments of DNA from other organisms into the plant genome using various techniques, such as Agrobacterium-mediated transformation, biolistics, or genome editing (Kumar et al 2020). These DNA segments, called transgenes, can alter the expression of existing genes or introduce new genes that code for novel proteins or enzymes. The transgenes are inherited by the offspring of the GM plants and can confer the desired traits to the next generation.

GM plants have been used for various purposes, such as increasing crop yield and quality, enhancing nutritional value, producing pharmaceuticals and industrial products, and improving environmental sustainability. Some examples of GM crops that are widely cultivated around the world are corn, soybean, cotton, canola, and rice. GM plants have also been developed for scientific research, such as studying gene function, plant physiology, and molecular biology.

Genetically modified (GM) plants are plants that have been altered by introducing new DNA into their genomes. This can give them new or improved characteristics, such as resistance to pests, herbicides, or diseases (Kumar et al 2008). There are different methods of developing GM plants, but the most common ones involve either using a gene gun or a bacterium.

1. **By Gene Gun Method**

A gene gun is a device that shoots tiny metal particles coated with the desired DNA into plant cells. The DNA then integrates into the plant's genome and expresses the new trait (Sanford et al 1987). This method can be used to transfer DNA from any source, including other plants, animals, or microorganisms. A gene gun can also introduce multiple genes at once, but it is not very precise and can cause damage to the plant cells.

2. **By Bacterium Method**

A bacterium is a living organism that can naturally transfer its DNA into plant cells. The most widely used bacterium for GM plants is Agrobacterium tumefaciens, which causes a disease called crown gall in plants. Scientists can modify the bacterium's DNA and insert the desired gene into a special region called the T-DNA. The bacterium then infects the plant cells and transfers the T-DNA into the plant's genome (Hiei et al 1997). This method is more precise and less damaging than the gene gun, but it can only transfer DNA from certain sources and it may not work for all plant species.These are some of the methods of development of genetically modified plants that are currently used by scientists and biotechnologists. They have advantages and disadvantages depending on the type of plant and trait that is being modified. GM plants have potential benefits for agriculture, food security, and environment, but they also raise ethical, social, and environmental concerns that need to be addressed.

Steps Involved in Development of Gm Plants

The development of genetically modified plants involves several steps that aim to introduce a desired trait into a crop species. The flow chart of the steps in development of genetically modified plants is as follows :(Chawla 2012).

1. Identify a trait of interest: This could be a trait that confers resistance to pests, diseases, herbicides, drought, or salinity, or that enhances yield, quality, or nutritional value of the crop.
2. Isolate the gene that controls the trait: This could be done by using existing knowledge about the gene structure, function, or location on chromosomes, or by

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using techniques such as PCR, DNA sequencing, or gene cloning to identify and amplify the gene of interest from a donor organism.

3. Design the gene to express in a specific way: This could involve modifying the gene sequence, adding regulatory elements such as promoters or terminators, or inserting marker genes that help to identify the transformed cells.
4. Insert the gene into the plant cells: This could be done by using physical methods such as biolisticsor electroporation, or biological methods such as Agrobacterium-mediated transformation or viral vectors, to deliver the gene construct into the plant cells.
5. Select and regenerate the transformed cells: This could be done by using selective media that contain antibiotics or herbicides that only allow the growth of cells that have incorporated the gene of interest, or by using molecular techniques such as PCR or Southern blotting to confirm the presence and integration of the gene. The transformed cells are then cultured in vitro to regenerate whole plants.
6. Test and evaluate the genetically modified plants: This could involve performing field trials, greenhouse experiments, or laboratory analyses to assess the expression and stability of the trait, the agronomic performance and environmental impact of the plants, and their safety for human and animal consumption.

GM Golden Rice

One of the latest examples of genetically modified plants is a transgenic rice variety that produces beta-carotene, a precursor of vitamin A, in its grains. This rice, known as Golden Rice, was developed to address the problem of vitamin A deficiency, which affects millions of people in developing countries and can cause blindness and increased susceptibility to infections. Golden Rice was created by inserting two genes from daffodil and one gene from a bacterium into the rice genome, using a technique called Agrobacterium-mediated transformation. The inserted genes enable the rice to synthesize beta-carotene in the endosperm, the edible part of the grain, giving it a golden-yellow color. Golden Rice has been tested for its safety, nutritional value, and agronomic performance in several countries, and has been approved for cultivation in some of them (Swamy et al. 2021). However, it has also faced opposition from some environmental and anti-GMO groups, who have raised concerns about its potential ecological and social impacts. Golden Rice is an example of how genetic engineering can be used to improve the nutritional quality of crops and address global health challenges (Qamar et al. 2020).

GM Mustard

One of the latest examples of genetically modified plants in India is GM mustard, which has been recently cleared for commercial cultivation by the Genetic Engineering Appraisal Committee (GEAC) under the Environment Ministry. GM mustard is a genetically engineered version of mustard that has been modified to include certain desirable traits, such as herbicide tolerance and hybrid vigour. GM mustard was developed by a team of scientists from Delhi University, led by Prof. Deepak Pental.

GM mustard is expected to increase the yield and quality of mustard oil, which is widely used in Indian cuisine. It is also expected to reduce the dependence on imported edible oils, as India is one of the largest importers of vegetable oils in the world. GM mustard is the first genetically modified food crop to be approved for cultivation in India, after a long and controversial regulatory process that involved several scientific studies, public consultations, and legal challenges.

However, GM mustard also faces opposition from various stakeholders, such as farmers' groups, environmental activists, consumer organisations, and religious groups. Some of the concerns raised by them include potential health risks to humans and animals, environmental impacts such as gene flow and effects on non-target organisms, socio-economic impacts such as loss of biodiversity and farmers' rights, ethical and religious issues such as violation of natural order and sacredness of life. These concerns have led to protests and petitions against the approval of GM mustard.

The debate on genetically modified crops in India reflects the complex and multidimensional nature of the issue, which involves scientific, legal, social, economic, ethical, and religious aspects. While genetic engineering offers a promising tool for crop improvement and food security, it also poses potential risks and challenges that need to be addressed with caution and transparency. The future of genetically modified crops in India depends on how well these issues are resolved through evidence-based decision making, public participation, and regulatory oversight.

Advantages of GM Plants

Genetically modified plants are plants that have had their genetic material (DNA) changed using biotechnology to give them desirable traits. Some of the advantages of genetically modified plants are:

- They can increase agricultural productivity by making plants more resistant to pests, herbicides, viruses, and environmental stress. This can reduce the need for pesticides and other inputs, and improve crop yields and quality (Kumar *et al*. 2020)
- They can enhance the nutritional value and flavor of plants by adding or modifying genes that produce beneficial substances, such as vitamins, minerals, antioxidants, or proteins. This can help address malnutrition and food insecurity in some regions of the world.
- They can extend the shelf life and attractiveness of plants by preventing bruising, browning, wilting, or spoilage. This can reduce food waste and increase consumer satisfaction.
- Higher yields and longer shelf life may lead to lower prices for consumers, and pest-resistant crops means that farmers don't need to buy and use as many pesticides to grow quality crops.

Genetically modified plants have many potential benefits for farmers, consumers, and the environment, but they also pose some challenges and risks that need to be carefully assessed and regulated.

Limitations of GM Plants

Some of the advantages of genetically modified plants are improved crop yield, resistance to pests and diseases, tolerance to abiotic stress, and enhanced nutritional quality. However, genetically modified plants also have some limitations and disadvantages that need to be considered.

One of the limitations of genetically modified plants is the uncertainty and complexity of their effects on the environment and biodiversity. Genetically modified plants may have unintended consequences on the ecosystem, such as gene flow, outcrossing, invasiveness, and impact on non-target organisms (Tsatsakis et al. 2017). For example, genetically modified plants that produce insecticidal toxins may harm beneficial insects or induce resistance in pests. Genetically modified plants may also affect the soil microbiome and nutrient cycling.

Another limitation of genetically modified plants is the ethical and social issues that they raise. Genetically modified plants may pose risks to human health, such as allergenicity, toxicity, and antibiotic resistance. Genetically modified plants may also raise concerns about food sovereignty, intellectual property rights, biosafety regulations, and public acceptance. Genetically modified plants may create conflicts between different stakeholders, such as farmers, consumers, industry, and governments (Hirschiet al. 2020).

Therefore, genetically modified plants have both benefits and drawbacks that need to be weighed carefully before their adoption and use. Genetically modified plants are not a panacea for the challenges of agriculture and food security, but rather a tool that requires careful evaluation and management.

Conclusion

Genetically modified plants are plants that have been altered by introducing new genes or modifying existing ones. They have been developed for various purposes, such as improving crop yield, enhancing nutritional quality, increasing resistance to pests and diseases, and producing novel substances. However, genetically modified plants also pose potential risks to human health and the environment, such as allergenicity, gene flow, loss of biodiversity, and ethical concerns. Therefore, the use of genetically modified plants should be carefully evaluated and regulated on a case-by-case basis, taking into account the benefits and drawbacks of each application. Genetically modified plants are not inherently good or bad, but rather depend on how they are used and what impacts they have on society and nature.

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