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GENETICALLY MODIFIED (GM) CROPS: BENEFITS AND CONTROVERSIES

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ABSTRACT

The data regarding genetically modified food is one of the leading arising fields of Plant Biotechnology difficulties reviewed and collected as a review paper from more than 40 published papers of transnational reputed journals, Annual/ Environmental Reports of honored associations, and e-books. The study was carried out with the objects to examine some reasons that are behind the genetically modified difficulties and give a better idea of what a genetically modified food is and how it affects mortal beings. This review paper includes colorful benefits and difficulties regarding genetically modified food, the positive and negative impacts of GM food on humanity and terrain, consumer stations to genetically modified food, and its unborn prospects. The recommendations were that there's a need for an accurate assessment of each crop for possible negative issues. IJSER Communication and networking amongst experimenters and pots is necessary and technology should be duly conducted to be effective. The development and consumption of genetically modified (GM) crops are girdled by contestation. According to proponents, only molecular biology approaches and inheritable engineering tools are realistic food deficit results for the world's ever-growing population. The main purpose of this study is to review the impact of GM products on mortal, beast, and environmental health. People still reject GM crops not only because of safety enterprises but also for moral reasons. Toxin, disinclinations, and possible horizontal gene transfer (HGT) to the terrain or other species have Myths and Realities about Genetically Modified Food. A Risk- Risk-benefit analysis of the marketing of GM products also, the scarce data available about the long-term counteraccusations of using GM crops is another opponent's concern. Nonetheless, wisdom has substantiated no detriment from GM crops use to date but has, rather, reported several benefits that affect their commercialization, similar to profitable, environmental, and health benefits for the general public. Legislation and programs about GM product labeling norms are being bandied. To overcome rising food security challenges, considering quality scientific information is essential rather than leaving the issue and simply moving toward moral discussion. Hence, a threat-benefit analysis is necessary.

Keywords: Genetically modified foods, Toxicity, Allergies, Horizontal gene transfer (HGT), A risk-benefit analysis.

INTRODUCTION OF GENETICALLY MODIFIED (GM) CROPS

The term GM food refers to crop plants that are created by using the latest molecular biology techniques for human or animal consumption (1). Plant Genetic modification occurs in following steps:-

1. Identify an organism with desired characteristic and the specific gene for this character is located and then cut off the DNA.

2. Attached the gene to a carrier (mostly plasmid) act as a carrier in order to introduce the gene into the cells of the plant to be modified.
3. Greenhouse is also added with the gene and carrier to confirm that the gene works effectively when it is introduced into the plant [2].
4. The target gene, carrier, and promoter are then introduced into the bacterium, which reproduces the gene to produce several copies, which are subsequently delivered to the transformed plant.
5. After that, it was determined whether or not the plants displayed the required physical traits that the new gene had bestowed.
6. The GM plants are crossed with the same type of conventional plants to create seed for more research and potentially future commercial applications. Up to ten years or longer may pass between the first gene selection and commercial manufacturing [3].

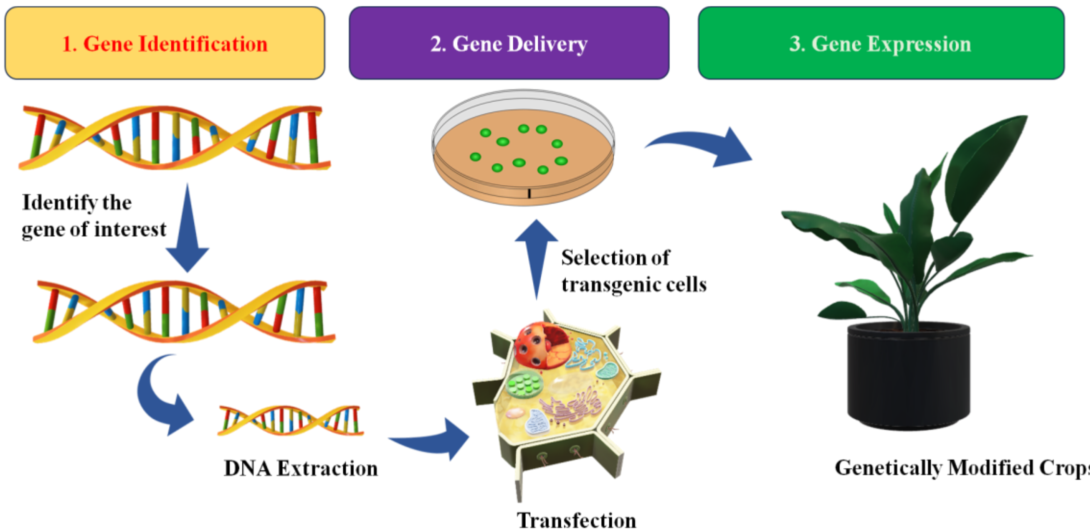

Fig 1: Steps for genetic modification in crop plant.

The estimated 9.8 billion people on earth by 2050 are expected to raise the demand for food nationwide [4]. This growth presents challenges in food production and consumption patterns, with meat demand growing the most and the cattle industry emitting the most greenhouse gases, impacting carbon emissions and land use.
Moreover, Climate change and less cultivable land pose challenges to food production, including rising temperatures, extreme weather events, fewer pollinating insects, water scarcity, and alterations in pest-crop relationships. Genetically modified crops could enhance sustainable food production [5].

Advancements in molecular biology and genetic engineering have led to improved traits in crops like herbicide tolerance and insect resistance [6]. Interest in GM crops with improved nutritional properties is growing, raising concerns about potential risks. The debate on using GMOs in food production raises concerns about health and environmental impacts, but supporters argue for crop enhancement advances for food security and meeting increasing demands [7].

HISTORY AND NEED FOR GM PLANTS

Biotechnology enables the exchange of genetic materials in food, known as genetically modified food (GMF). The first GMF was introduced in the 1960s with the Lenape potato, but later, a new potato variety called solanine caused a toxin [8].

Genetic engineering, while potentially harmful to plants and animals, offers numerous health benefits and is crucial for the growing world population of six billion, which is expected to double in the coming years [6]. The current research funding for genetically modified crops is better spent on other plant science areas like nutrition, policy research, governance, and local market conditions, rather than on GM crops, which needs to make sure the growing population gets an adequate supply of food. Research shows genetic engineering products are easier to control, nontoxic, and beneficial for health, environment, and cost-effectiveness, outweighing risks [9].

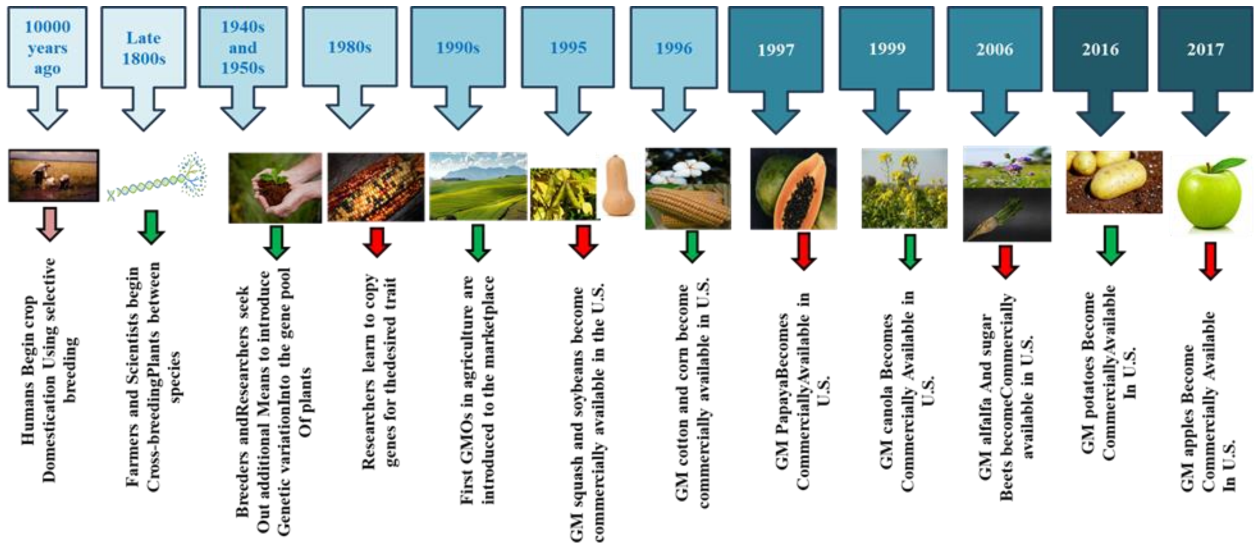

Fig 2: History and evolution of GM Crops

The Green Revolution of the 1960s significantly accelerated global food production, driven by technological innovations like synthetic fertilizers, higher-yielding grain varieties, mechanized agriculture, and high-yield practices like mono-cropping, contributing to a growing global population's calorie demands. Malnutrition remains a significant global health risk, with 2 billion people deficient in micronutrients, 820 million hungry, and 26.4% affected by food insecurity. Undernourishment is linked to 3 million child deaths annually [10].

The projection of 9 billion people on our planet by 2050 are anticipated to increase the demand for food worldwide. This growth presents challenges in food production and consumption patterns, with meat demand growing the most and the cattle industry emitting the most greenhouse gases, impacting carbon emissions and land use [11].

Technological advancements in molecular biology and genetic engineering have led to improved crop traits and nutritional properties. However, such as herbicide tolerance, good insect resistance, or better yields the debate surrounding the use of GMOs remains significant. Supporters argue that these advancements could ensure food security and meet growing demands. This review examines the risk-benefit analysis of GM food consumption to highlight its potential benefits [12].

BENEFITS AND CONTROVERSIES

Public debates concerning the pros and cons of genetically modified (GM) crops remain, however, farmers in many nations are rapidly implementing these crops. Independent science academies and regulatory bodies have concluded that commercialized GM crops are safe for human consumption and the environment, with benefits such as higher yields, cost savings, and welfare gains. However, the real risk-benefit analysis will take place in developing countries, particularly among the poorest people, due to mistrust of multinationals and the Precautionary Principle [13].

Plant biotechnology poses potential risks to the environment, human health, and food system sustainability. Advocates argue that genetic modification (GM) technology is similar to traditional plant-breeding techniques, as humans have been breeding plants for thousands of years. They argue that GM speeds up the process and is only slightly different from traditional methods [14].

A meta-analysis aims to consolidate evidence on the mixed impact of GM crop technology, addressing public suspicion and potential data and methodological issues.

The meta-analysis of GM crop impacts includes recent studies, broadening geographical areas, methods, and outcome variables. It also evaluates whether, the reception of GM crops alters the amount of chemical pesticides, which became a limitation of prior studies. The approach uses meta-regressions to explain impact heterogeneity [15].

BENEFITS

The meta-analysis examines the impact of genetically modified crops (GM) on crop yield, pesticide quantity, cost, total production cost, and farmer profile. Benefits include pest resistance, cold tolerance, herbicide tolerance, nutrition, pharmaceuticals, and environmental monitoring [16].

Pest Resistance:
For protecting crops against insect pests, genetic modification increases yields and lowers the need for chemical pesticides. Monsanto created Bt corn and Bt cotton to produce insect control proteins, and Bollgard (BT) cotton reduces pests to improve production, save costs, and boost profits [1].

Herbicide Tolerance:
When certain techniques, for instance, tilling, make it difficult to eradicate weeds, farmers often spray plenty of herbicides to clear the weeds, but this technique is tedious and costly. Besides being herbicide-resistant, GM crops also protect the environment by using fewer herbicides altogether. These crops use DNA from soil bacteria to withstand the use of potent herbicides. The 'wide range' weed killers that the GM crops can withstand can be sprayed on the entire field, eradicating anything excluding the GM crop. Transgenes that confer tolerance to the herbicides glyphosate or glufosinate ammonium are examples of herbicide-tolerant crops. Except for plants with the tolerance gene, almost every type of plant is killed by these herbicides [17].

Temperature Tolerance:
An abrupt chill impacts sensitive seedlings. It could be hard to grow some crops in specific climates for plenty of reasons. Strawberries are tricky to grow in cold climates, for example, because they are not very frost-hardy. According to recent research, the arctic flounder produces an anti-freeze protein to protect itself in arctic seas. Through the expression of this anti-freeze gene, genetically modified strawberries or soybeans may be able to survive in adverse conditions and prevent the damaging effects of frost [5].

Improve Nutrition:
Since the dependence on a single crop, malnutrition is fairly common within developing nations. As rice is their primary meal, it fails adequate nutrients to safeguard them from becoming malnourished. Future GM crops might directly benefit consumers in substantial ways, whether nutritionally or medically. Essential micronutrients are incorporated into the human diet by genetically engineered crops. One such crop is "golden rice," which is genetically modified to produce beta carotene, the precursor to vitamin A [18]. One promising method to address vitamin A deficiency is genetically modified "golden rice." Some Asian and African populations that are malnourished may benefit from this kind of crop. It is also possible to genetically modify canola to improve its vitamin E content or balance its fatty acid composition [19].

Pharmaceuticals:
Therapeutic proteins are required for the production of biopharmaceuticals, including vaccines, enzymes, antibodies, and blood proteins. Pure, safe, and effective medicinal proteins are produced from genetically engineered plants. Shortly, edible vaccinations that are convenient to transport and store will be manufactured in potatoes and tomatoes. Inactivated viruses found in transgenic (or genetically modified) bananas have been created to guard against common diseases found in developing nations, including cholera, hepatitis B, and diarrhea [20]. These kinds of genetically modified crops that manufacture vaccinations might be safer than conventional vaccines, whose extra ingredients frequently have negative side effects because they would only produce the required antigens.

Environmental Monitoring and Remediation:
These days genetically modified products—like plants that extract toxic elements from polluted soil—are employed to tackle environmental pollution, which is the greatest threat threatening the entire globe deployed as indications of pollution as well [19]. According to Rugh (2004), plants are also capable of metal phyto-extraction and organic compound phyto-degradation. Several plants, including Arabidopsis thaliana and Tobacum nicotiana, were

genetically enhanced with non-plant transgenes to improve the potency of phytoremediation against a variety of contaminants, including nitroaromatic explosives, organomercurials, and trichloroethylene solvents. Furthermore, plants might be designed to create biodegradable industrial raw materials (like bioplastics), which would lessen the amount of non-biodegradable plastics that end up in the environment. Moreover, GM trees can be used in bioremediation to control heavy metal contaminants [21].

CONTROVERSIES

Food Allergenicity:
Increasing food allergies among the human population is one of the negative consequences of genetically modified food. The symptoms of food allergies usually appear minutes after intake and are mediated by immunoglobulin (IgE) antibodies. In order to assess the allergenicity of genetically modified foods or crops, the FAO and WHO (2001) recommend finding the amino acid sequence, characterizing it, and utilizing animal models that diagnose food allergies in the same way as human diseases do [22].

Antibiotic Resistance:
When an organism is unaffected by an antibiotic, antibiotic resistance occurs. Foreign genes often link to another gene as an antibiotic resistance marker gene (arm) when they are inserted into plants. Food bearing an antibiotic resistance gene might have side effects [23]. Consuming these foods that contain antibiotics reduces their ability to resist bacterial illnesses. These unique combinations could lead to the increasing threat of antibiotic drug resistance to public health. Bees that ingest gene-modified rapeseed (canola) plants have bellies that contain bacteria resistant to antibiotics, according to German researchers. Because Novartis' genetically modified Bt corn contains an ampicillin resistance gene, European nations have rejected its growth [24].

GE Super-weeds and Super-pests:
Genes tolerant to drugs are transmitted through weeds into super-weeds. Several GM crops, for instance rapeseed, impart genes of herbicide resistance to aligned weeds, such as mustard plants. Multiple investigations predicted that cotton bollworms, which lurk within genetically engineered crops, may soon become superweeds. Organic farmers are at risk since their management techniques won't be able to keep up with the growing quantity of weeds and super-pests. Certain traits that are weed-like in crops including Medicago sativa, Brassica napus, Brassica rapa, Helianthus annuus, and Oryzae sativa will soon grow weedier. Transgenic protein-resistant insect pests may shorten the time it takes to cultivate an insecticidal transgenic variety [25]. For example, the diamond black moth, a pest of Brassica crops, demonstrated tolerance to the application of Bt toxins.

Adverse Effects on Non-Target Species:
Genetically modified crops that carry insecticidal transgenes and are employed to manage agricultural pests may have an impact on non-target species. The transgenic crops' pesticidal gene product may be detrimental to the species that use it; for instance, Bt endotoxins have been shown to have toxic effects on non-target species. Only specific species or groups of insects, such as Lepidoptera, Coleoptera, or Diptera, were affected by this toxicity. Although Bt genes do not affect plant species [26].

Increase in Anti-nutrients:
The introduction of a new gene can raise the quantities of anti-nutrients that are currently present and cannot be eliminated by heat. Roundup-resistant to glyphosate Commercial GM soybeans that exhibit a rise in anti-nutrients are known as "ready soybeans." Phytic acid, glucinins, and phytoestrogens are heat-stable anti-nutrients that cause infertility in sheep and cattle. Increased levels of anti-nutrients are undesirable when GM food is consumed as a raw material [27].

ETHICS AND POLICIES FOR GM CROPS REGULATION

Expert bioethicists, like the European Commission's GAEIB, discuss the moral implications of genetically modified organisms (GMOs). The most important issues, however, cannot be adequately addressed by the current regulatory framework. The necessity for regulators to portray their conclusions as science-based limits the scope of potential outcomes and hinders the risk assessment process. In addition to scientific evidence, risk assessment relies on expert opinions regarding the acceptability, plausibility, and importance of impacts. Because science-based decisions are not value-free and subjectivity is exacerbated when the issue is uncertainty rather than risk, two arguments for value-driven ethical questions are outside the regulatory purview [2]).

GM Crops and National Laws

The International Framework for Genetically Modified Organisms (GM) crops and Intellectual Property Rights (IPR) are crucial for the global trade of GMOs. The WTO-TRIPS Agreement, the CBD, and the International Seed Treaty are key institutions that regulate around 95% of global trade. The agreement provides patents for inventions in all fields of technology, including products and processes, without discrimination. Members may exclude inventions that protect public order or morality, human, animal, or plant life or health, or avoid serious environmental prejudice. However, the TRIPS agreement promotes private appropriation of benefits and lacks an explicit mechanism for acknowledging traditional knowledge in the industrial use of genetic resources. To give new plant varieties sui generis protection, the CBD amended the Patent Act of 1970 and passed the PPVFR Act of 2001 [29]. India has established intellectual property rights (IPR) laws in compliance with international treaties to regulate genetically modified (GM) crops. These crops are created through biotechnological methods to achieve desired traits. The evolution and regulation of GM crops, their benefits and associated risks, and the intersection of GM crops and IPR laws in India. It also covers environmental laws and institutional frameworks in India that ensure the safe development, release, and commercial approval of GM crops in line with international standards. Notable examples of GM crops in India include Bt Cotton, Bt Brinjal, and GM Mustard, which have been subject to extensive debate and regulatory scrutiny. These crops aim to address specific agricultural challenges, such as pest resistance and improved yield, contributing to more sustainable farming practices [30].

The Constitution of India does not explicitly mention GM organisms, but the DPDP mandates the state to develop agricultural products and animal breeds, including GM organisms, by modern science. The treaty also allows for the disclosure of passport data and non-confidential descriptive information but bars certain industrial uses. Access to PGR for food and agriculture is protected by intellectual and property rights, consistent with international agreements and national laws [31].

India has adopted two key legal instruments, the Convention on Biological Diversity (CBD) and the Cartagena Protocol on Biosafety, to ensure the safety of GM crops, environment, and biosafety. The CBD convention, adopted at the 1992 Earth Summit, focuses on biodiversity and environmental conservation, particularly originating from genetically or living modified organisms (GMO/LMOs). It requires projects like the development of GM crops to have an impact assessment and adopt measures for minimizing adverse impacts on the conservation of biological diversity, sustainable use of its components, and fair and equitable sharing of benefits from the use of genetically modified organisms. The Cartagena Protocol on Biosafety, adopted in 2000, is primarily concerned with the transboundary movement of LMOs and provides a framework for countries to assess risks associated with LMOs before authorizing them within their jurisdiction or control. India has implemented three key acts to regulateat development, release, and commercial approval of GM crops, including the Seed Act 1966 and the Seeds (Control) Order [29].

To carry out biotechnology research in labs, the National Biotechnology Board was founded in 1983. In 1986, it was converted into the Department of Biotechnology (DBT) under the Ministry of Science and Technology (MOST) to monitor, develop safety guidelines, and promote biotechnologies in India. Later, biotechnology-related work was reallocated to the Ministry of Environment and Forest (MoEF), which implemented the Food Safety and Standard Act 2006 and the Seed Act 1966 & the Ministry of Agriculture's (MoA) Seeds (Control) Order. The EPA 1986 rules, which came into force in 1993, regulate GMOs and GM crops as inherently harmful substances. The DBT was assigned to handle various aspects of GMOs to ensure inter-ministerial coordination. India has established intellectual property rights (IPR) laws in compliance with international treaties to regulate genetically modified (GM) crops (33). These crops are created through biotechnological methods to achieve desired traits. The evolution and regulation of GM crops, their benefits and associated risks, and the intersection of GM crops and IPR laws in India. It also covers environmental laws and institutional frameworks in India that ensure the safe development, release, and commercial approval of GM crops in line with international standards. Notable examples of GM crops in India include Bt- Cotton, Bt- Brinjal, and GM Mustard, which have been subject to extensive debate and regulatory scrutiny. These crops aim to address specific agricultural challenges, such as pest resistance and improved yield, contributing to more sustainable farming practices. The Constitution of India does not explicitly mention GM organisms, but the DPDP mandates the state to develop agricultural products and animal breeds, including GM organisms, following modern science (34). The treaty also allows for the disclosure of passport data and non-confidential descriptive information but bars certain industrial uses. Following international accords and national regulations, intellectual and property rights safeguard access to PGR for food and agriculture. India has adopted two key legal instruments, the Convention on Biological Diversity (CBD) and the Cartagena Protocol on Biosafety, to ensure the safety of GM crops, environment, and biosafety. The CBD convention, adopted at the 1992 Earth Summit, focuses on biodiversity and environmental conservation, particularly originating from genetically or living modified organisms (GMO/LMOs) (35). It requires projects like the development of GM crops to have an impact assessment and adopt measures for minimizing adverse impacts on the conservation of biological diversity, of its elements, as well as the just and equal distribution of advantages resulting from the application of genetically modified organisms. The Cartagena Protocol on Biosafety, adopted in 2000, is primarily concerned with the trans-boundary movement of LMOs and provides a framework for countries to assess risks associated with LMOs before authorizing them within their jurisdiction or control. India has implemented three key acts to regulate at development, release, and commercial approval of GM crops, including the Seed Act 1966 and the Seeds (Control) Order. In order to carry conduct biotech research in labs, the National Biotechnology Board was established in 1983.In 1986, it was converted into the Department of Biotechnology (DBT) under the Ministry of Science and Technology (MOST) to monitor, develop safety guidelines, and promote biotechnologies in India. Later, biotechnology-related work was reallocated to the Ministry of Environment and Forest (MoEF), which implemented the Food Safety and Standard Act 2006 and the Seed Act 1966 & the Ministry of Agriculture's (MoA) Seeds (Control) Order. The EPA 1986 rules, which came into force in 1993, regulate GMOs and GM crops as inherently harmful substances. The DBT was assigned to handle various aspects of GMOs to ensure inter-ministerial coordination [32].

CONCLUSION

The study analyzes micro-level data from individual plots and/or farms to simulate the agronomic and/or economic effects of GM soybean, maize, or cotton. There are rather limited impact studies available for other GM crops, such as GM papaya, GM sugar beet, and GM rapeseed, despite considering that these products were commercialized in several nations.

The study uses one or more of the following outcome variables—yield, pesticide quantities (particularly insecticides and herbicides), pesticide expenses, total variable costs, gross margins, and farmer profits—to describe the effects of GM crops. If just the number of pesticide sprays was provided, this was used as a stand-in for pesticide quantity.

Either means outcomes for GM and non-GM crops, absolute or percentage differences, or estimated coefficients of regression models that can be used to compute percentage differences between GM and non-GM crops are utilized in the study to examine the performance of GM crops.

Only one publication was included to prevent double counting when the same results were reported in many publications. However, some publications include multiple impact observations, even for a single outcome variable. This is, for example, when results are reported for different regions or derived using different methods (e.g., comparison of mean outcomes of GM and non-GM crops plus regression model estimates). All observations were incorporated in those instances.

Moreover, the same primary dataset was often used for several publications with distinct findings (e.g., different methodologies, different waves of panel data, and study of various outcome variables). Therefore, our sample comprises larger-scale observations than articles and original datasets.

Only a few number of GM crops have been authorized to be produced as food. However, the fresh challenges of climate change, sustainability, and global food safety could be tackled by advancing the creation of GM crops utilizing

GE technology. Despite the increasing number of genetically modified crops being introduced to the market, some consumers and the scientific community continue to oppose them. One of the main concerns is the threat whether consuming GM crops might threaten the health of people, animals, or the environment in the long term, making it difficult to determine. GMOs are historically connected to some threats, such as toxicity issues, allergy development, tumor growth, infertility, and the potential for transgene(s) to spread horizontally to other species or the environment. But there isn't enough scientific proof to say that they are hazardous to health. The substantial equivalence concept, as stated by the OECD, states that GMOs are just as safe as conventional foods. The use of genes that confer antibiotic resistance as selectable markers has been prohibited, notwithstanding the low likelihood of horizontal gene transfer.

There are still concerns about genetically modified foods despite the fact many items on the market, like processed meats and alcohol, are listed on the WHO list of foods that cause cancer. Based on population studies, ethical aspects of GMOs seem to be seen unfavorably.

As described above, GM food may assist in resolving the nutritional deficiencies of future generations while simultaneously combating climate change and offering improvements beyond such broad considerations that the general public mostly overlooks. Therefore, consumers should be informed of this reported consumer health advantage.

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