Global Acceptance versus Indian Resistance: A Comparative Analysis of Genetically Modified Crops

Grishma Bhavsar*

Assistant Professor, Faculty of Law, GLS University, Gujarat, India

**Corresponding Author Email: grishma1807@gmail.com*

Abstract: *Concerns over global food security have become more serious than ever as the world's population keeps growing exponentially on the other hand the amount of arable land keeps reducing. Such challenges have led to an increase of research towards innovative agricultural solutions. One such solution is the development of Genetically Modified (GM) crops, such crops are modified in a manner to improve the features such as pest resistant, herbicide tolerance, ability to survive environmental stress, etc. These crops are developed through incorporating genes from other organisms to get the desired result. GM crops have the potential to provide a range of benefits, including higher crop yields, decreased production costs, and greater nutritional value. However, there is still continuous debate about their use around the world, with health and environmental issues frequently at the center of discussion. India has adopted GM technology with more caution than many nations around the world. So far the government has approved only a few varieties of GM cotton, specifically Bacillus Thuringiensis (Bt) cotton for its cultivation. In this research paper an attempt has been made to examine the concept of GM crops, their advantages as well as potential risks involved. It also investigates the global acceptance of GM crops and compares India's position with that of other nations. It also highlights the legal and regulatory framework governing the use of GM crops in India offering the insights into the country's cautious approach and its implications for agricultural development.*

Keywords: Bacillus Thuringiensis (Bt), Biotechnology, Environment, Food Security, Genetically Modified Crops.

INTRODUCTION

According to the United Nations report, the world's population is expected to increase from 8.2 billion to roughly 10.3 billion during next fifty years(United Nations, Department of Economic and Social Affairs, Population Division, 2024). This fast-growing population places additional pressure on the global food system, which is already facing challenges due to environmental issues and political problems. As the population is increasing, the demand to feed safe, affordable and nutritional food would also increase. The ability to meet the rising demand for food has been limited by a number of significant challenges such as changing weather patterns which include rising temperature, extreme occurrence of drought, flood or storm. Additionally, the fertility of soil has decreased globally due to soil deterioration brought on by contamination, erosion, and misuse, which reduces the land's capacity to sustain agricultural production. A decreasing quantity of fresh water accessible for agriculture is another alarming point. Furthermore, the growing number of plant diseases and continued political instability pose a significant danger to food security. In light of these growing pressures, innovative and sustainable approaches are urgently required to ensure global food security. To fulfil the increasing demand of a world population which is expanding at an accelerated rate, recent developments in biotechnology have brought about novel ways to enhance not only the quality of food but also its quantity (Ekici & Sancak, 2017). Biotechnology is one area where we can find the solution to fulfil the dietary needs of growing population by producing nutritious food. Scientists can now design better sorts of crops that yield more food, have more nutrients as compared to the naturally grown food products, and can withstand harsh conditions such as flood, drought, pests, and diseases by using technologies such as genetics and biotechnology. Biotechnology is a broader field which uses living organisms to develop or make products, it can include traditional methods like fermentation and as well as modern methods like tissue culture, cloning and genetic engineering. Genetic Modification is a subset of biotechnology which involves direct manipulation of an organism's DNA using molecular tools. Genetically Modified (GM) crops have already proved the ability to increase yield while reducing the need for pesticides and fertilizers, thereby offering an option for addressing food insecurity. This research paper attempts to examine the concept of GM crops, their benefits as well as associated risks on both human health as well as environment, the status of GM crops grown around the world and where India stands in comparison to the globe, and the legal and regulatory framework which govern the use of such crops.

DOI: https://doi.org/10.62656/SIJSS.v24i2.2355

GM CROPS: AN OVERVIEW

Biotechnology has significantly expanded the scope of genetic recombination, which involves the transferring of genes from one living organism to another or modifying existing genes inside an organism, these interventions result in the expression of unique features that were not previously present in the organism (Karalis et al., 2020). Genetic modification (GM) is that branch of biotechnology which has focused on the deliberate modification of genetic material in living organisms to allow them to perform certain desirable end results (Raman, 2017). This method includes directly manipulating the DNA either through adding, deleting, or changing specific genes to get the desired result by introducing new features. Unlike the traditional breeding procedures, which rely on the natural exchange of genetic material between closely related species, genetic modification enables the scientists to transfer genes between wholly unrelated species. This is achieved through number of ways, such as using gene guns, electroporation, microinjection, or employing bacteria like Agrobacterium-mediated transformation to transfer the genetic material (Wang et al., 2025). After the new gene has been successfully integrated into the plant cells, these GM cells are cultivated in controlled environments to regenerate into complete plants (Yuan et al., 2024). The plants which has been developed from these cells are capable of producing seeds that stably inherit and express the introduced traits across subsequent generations. Through such innovative methods, the living organisms specifically the crops can be modified to have increased resistance to pests and diseases, tolerance to environmental pressures, higher nutritional content, etc. For example, biofortified crops such as Golden Rice that have been engineered to produce â-carotene, addressing vitamin A deficiency in populations where rice is a staple food (Sainger et al., 2015). Similarly, multivitamin maize has been designed to increase the content of multiple vital elements, providing a viable solution to hunger in resource-constrained areas. Crop resilience is also improved by GM technology; crops such as Bt cotton and Bt corn express proteins from the bacterium Bacillus thuringiensis, conferring resistance to specific insect pests and reducing the need for chemical pesticides (Gervais et al., 2025).

FEW EXAMPLES OF GM CROPS

GM crops have become known as an essential aspect of modern agriculture in recent decades, providing creative answers to some of the most important problems that farmers and consumers throughout the world are currently facing. New features that are hard or impossible to attain through conventional breeding procedures can now be introduced into crop plants by scientists using advanced genetic engineering techniques. Genetic engineering involves simply adding, deleting, or manipulating a single trait in an organism to create a desired modification (Shetty et al., 2017). These changes have produced crops that are more resilient to plant diseases and insect pests, more tolerant to herbicides and stresses from the environment like drought or salinity, and even crops with better nutritional profiles or longer shelf lives. GM crop acceptance has improved food security in many areas, decreased dependency on chemical pesticides and herbicides, and raised agricultural output. Below mentioned are the examples of widely accepted GM crops grouped according to the main traits and benefits for which they have been developed.

Bt Crops –Bt crops are a type of GM plants that guard themselves against certain harmful insects. These crops are modified artificially using a natural bacterium named Bacillus thuringiensis, which produces proteins that are toxic to specific pests but safe for humans and beneficial insects. Some examples of Bt crops include Bt corn, Bt cotton, and Bt brinjal, which have been developed to control common insect pests (Tabashnik et al., 2023). For instance, Bt corn helps control the corn borer, Bt cotton protects against the bollworm, and Bt brinjal combats the fruit and shoot borer. Using Bt crops reduces farmers' dependency on chemical insecticides, which is better for the environment. Farmers who grow Bt crops often experience higher yields and lower costs for pesticides. Additionally, these crops can help reduce pest populations in surrounding fields that do not use Bt technology, benefiting other farmers as well. However, over time, some pests may develop resistance, so it is important for farmers to use effective pest management practices to deal with this issue.

Herbicide-Tolerant (HT) Crops – Herbicide-tolerant (HT) crops, including glyphosate-resistant soybean, canola, sugar beet, and alfalfa, have been genetically modified to resist certain herbicides that would normally harm or ruin the plants. This trait allows for more effective and flexible weed control, reducing the need for mechanical tillage and contributing to soil conservation and reduced erosion. The use of HT crops has greatly enhanced farming productivity by making weed control easier and cutting down on labor and fuel expenses. Less frequent tilling also helps improve the soil's structure and its ability to hold moisture. However, depending too much on a single herbicide, especially glyphosate, has led to the development of weed species that are resistant to these chemicals (Ngongolo&Mmbando, 2025).

Nutritionally Enhanced Crops – Nutritionally improved GM crops are created to address shortages of essential nutrients in people's diets, especially in areas where poor nutrition is common. One well-known example is Golden Rice, which has been modified to contain â-carotene, a substance that the body can convert into vitamin A. This helps fight vitamin A deficiency in communities that rely heavily on rice as a staple food. Other examples include soybeans with higher levels of oleic acid, which provide healthier fats; rice enriched with iron; and maize fortified with several important vitamins and minerals. These crops have the potential to greatly enhance health outcomes, particularly in low-income countries where nutrient deficiencies are widespread.

Quality-Improved Crops – Some GM crops have been created to improve the quality of produce after harvest and make them more appealing to consumers. For example, certain apples, like the Arctic Apple, and potatoes have been designed to prevent enzymatic browning, which helps them stay fresh longer and reduces the amount of food that gets wasted (Noack et al., 2024). Another example is the Innate Potato, which has been modified to produce less acrylamide, a substance that may be harmful to health, when it is fried. Additionally, pink-fleshed pineapples have been developed

to contain higher levels of lycopene, providing them with a distinctive look and possibly offering health advantages. These examples include non-browning apples, Innate potatoes, and pink pineapples.

Virus-Resistant Crops – To combat deadly plant viruses that are uncontrollable by chemicals, GM crops that are resistant to viruses have been developed. One prominent example is papaya ringspot virus-resistant papaya, which protected the Hawaiian papaya sector from extinction. Similarly, virus-resistant squash and plums have been developed to tolerate infections that would normally result in major crop losses. These enhancements help to maintain yields and remove the need for chemical treatments, which promotes more sustainable production systems. Virus-resistant crops may include papaya, squash, and plum, also known as honey sweet plum.

PROS AND CONS OF GM CROPS

GM crops have been an ongoing subject for debate worldwide, with strong views both in favor and against its use. The positive aspects of GM crops include increased agricultural yields, disease and pest resistance, drought and herbicide tolerance, and a decreased demand for chemical pesticides and fertilizers. Especially in regions with challenging farming conditions, these qualities assist farmers save money, reduce crop damage, and enhance the availability of food (Brookes & Barfoot, 2020). Some GM crops are also designed to be more nutritious, like Golden Rice and iron-rich grains, which can help fight malnutrition in poorer countries (Abdul Aziz et al., 2022). Other examples, such as non-browning apples and longer-lasting tomatoes, help reduce food waste and make food products more desirable for their extended shelf life. However, there are also significant concerns regarding GM crops such as environmental impact, ethical considerations, socioeconomic implications, etc. Environmental issues include the risk of weeds becoming resistant to herbicides, harm to beneficial insects and other non-target species, and a decline in biodiversity. There may be an allergenic effect especially to those who are predisposed to allergies (Karalis et al., 2020). Animal experiments have revealed a variety of consequences, including weight increase, abnormalities to the kidneys and pancreas, immune system toxicity, and blood biochemistry abnormalities. Additionally, the reliance on a small number of large seed companies can lead to unfair business practices and limit farmers' freedom to choose their own seeds.

GM CROPS AROUND THE WORLD

The global situation regarding approvals for GM crops shows a wide difference in how countries adopt them. According to data as shown in figure – 1 compiled from International Service for the Acquisition of Agri-biotech Applications (ISAAA), the United States is at the top with approvals for 23 different GM crops, which highlights its strong biotechnology system and a regulatory environment that has regularly encouraged agricultural innovation. Canada is next with 20 approved crops, while Argentina and Brazil have approved 19 and 17 crops respectively, showing broad acceptance of GM technology in the Americas, especially in countries that rely heavily on agricultural exports. Other technologically advanced countries like Australia, China, and Japan have approved between 10 to 12 GM crops, showing a moderate level of adoption that is influenced by scientific progress and policy decisions. On the other hand, many developing countries take a more cautious or limited approach. Countries in Asia and Africa, such as South Africa, the Philippines, Paraguay, and Mexico, have approved between 4 to 8 GM crops, mostly focusing on staple foods and feeds like maize, soybean, and cotton. India, however, has approved only two GM crops: cotton and mustard. Bt cotton is the only GM crop currently grown on a large scale, while the approval for GM mustard has faced legal issues and public opposition, slowing its introduction (Kathage& Qaim, 2012). Compared to countries like Bangladesh, which has successfully introduced Bt brinjal, India's progress seems limited, even though it has one of the largest agricultural biotechnology research programs. Moreover, countries with similar developmental stages, such as Brazil and Argentina, have adopted a wider range of GM crops, which shows India's slower progress in policy and commercialization. Regulatory challenges, public doubt, and the lack of a unified national biotechnology strategy have all contributed to this slow development.

SCENARIO OF GM CROPS IN INDIA

India has adopted a cautious and controlled approach to the use of GM crops. The only GM crop that has been approved for farming is Bt cotton, which was introduced in 2002 (ISAAA, 2025). Since then, Bt cotton has been widely accepted by Indian farmers because it has helped increase crop output and cut down the need for pesticides. The large-scale cultivation of Bt cotton has also brought about better earnings for many cotton farmers, particularly those in central and southern parts of the country. Even though Bt cotton has proven to be beneficial, the approval process for other GM food crops, such as Bt brinjal and GM mustard, has been delayed for a long time and has been the subject of much debate. Such crops have not yet been approved for commercial production, owing to concerns about biosafety, environmental impact, food security, and ethical difficulties. Environmental groups, farming communities, and civil society organizations have all expressed strong opposition to these GM crops, citing a lack of public involvement, transparency in testing, and long-term impact on both health and environment. This opposition has hampered the further adoption of GM technology in India

India's biotechnology policy promotes research and innovation, and numerous governmental and private institutions are working to develop GM traits for a variety of crops, including rice, wheat, and pulses. However, the commercial use of GM crops is closely controlled by regulatory agencies such as the Genetic Engineering Appraisal Committee (GEAC), which undertakes thorough examinations before authorizing any GM product for cultivation. This highlights the commitment of India to the precautionary principle, which states that scientific development is encouraged but only allowed to proceed after complete safety assessments. Compared to countries like the USA, Brazil, and Argentina, which have approved and are growing a variety of GM crops, India's progress has been much slower.

Data on GM Crops Approved around the world by ISAAA Inc.																																
Country Name	Alfalfa	Apple	Argentine Canola	Bean	Carnation	Chicory	Cotton	Cowpea	Creeping Bentgrass	Eggplant	Eucalyptus	Flax	Maize	Melon	Papaya	Petunia	Pineapple	Plum	Polish Canola	Poplar	Potato	Rice	Rose	Safflower	Soybean	Squash	Sugar Beet	Sugarcane	Tobacco	Tomato	Wheat	Total GM Crops Grown
United States	√	√	√			√	√		√			√	√	√	√	√	√	√			√	√	√		√	√	√	√	√	√	√	23
Canada	√	√	√				√					√	√		√		√		√		√	√			√	√	√	√		√		16
Australia	√		√		√		√						√								√	√	√	√	√		√				√	12
China			√				√						√		√	√				√		√			√		√			√		10
Colombia			√		√		√					√	√									√	√		√		√				√	10
Japan	√		√		√		√						√		√						√		√		√		√					10
Mexico	√		√				√						√								√	√			√		√			√		9
New Zealand	√		√				√						√								√	√			√		√				√	9
Philippines	√		√				√			√			√								√	√			√		√					9
Argentina	√						√						√								√			√	√			√			√	8
European Union			√		√		√						√								√				√		√		√			8
Malaysia	√		√		√		√						√								√				√		√					8
Brazil				√			√				√		√												√			√			√	7
Singapore	√		√				√						√								√				√		√					7
South Korea	√		√				√						√								√				√		√					7
Vietnam	√		√				√						√												√		√					6
Indonesia			√										√								√				√			√				5
Nigeria							√	√					√												√						√	5
Russia													√								√	√			√		√					5
South Africa			√				√						√									√			√							5
Taiwan			√				√						√												√			√				5
Iran			√										√									√			√							4
Paraguay							√						√												√						√	4
Switzerland			√				√						√												√							4
Chile			√										√												√							3
Costa Rica							√						√												√							3
Ghana								√					√												√							3
Honduras													√									√										2
India							√																		√							2
Kenya							√						√																			2
Pakistan							√						√																			2
Thailand													√												√							2
Turkey													√												√							2
Uruguay													√												√							2
Bangladesh										√																						1
Bolivia																									√							1
Burkina Faso							√																									1
Cuba													√																			1
Egypt													√																			1
eSwatini							√																									1
Ethiopia							√																									1
Myanmar							√																									1
Norway					√																											1
Panama													√																			1
Sudan							√																									1
Zambia													√																			1

(Figure – 1) Compiled from Acquisition of Agri-biotech Applications (ISAAA)

LEGAL FRAMEWORK REGULATING GENETICALLY MODIFIED CROPS IN INDIA

In India, the regulation of GM crops is facilitated by a comprehensive legal and institutional structure aimed at ensuring biosafety, preserving the environment, and safeguarding food security. The Environment Protection Act of 1986 serves as the principal legislation governing GM crops, with the Rules for the manufacture, use, export, import as well as storage of Hazardous Microorganisms/ Genetically Engineered Organisms or Cells, 1989 (often referred to as the 1989 Rules) acting as the principal foundation for the nation's biosafety system. These rules are implemented by various regulatory bodies. The GEAC, functioning under the Ministry of Environment, Forest and Climate Change (MoEFCC), is the highest-ranking body responsible for granting approval for the environmental release of genetically modified organisms, including GM crops, after rigorous biosafety assessment (Singh, 2021). Prior to GEAC's examination, multiple committees, such as the Review Committee on Genetic Manipulation (RCGM), the Depart of Biotechnology (DBT), the Ministry of Science and Technology, Institutional Biosafety Committees (IBSCs) at research institutions, State Biotechnology Coordination Committees (SBCCs), and

District Level Committees (DLCs), contribute to the process (Shukla et al., 2018). The Food Safety and

Standards Authority of India (FSSAI) oversees the regulation of GM foods under the Food Safety and Standards Act, 2006. Before any food product derived from GM organisms can be marketed, it must obtain FSSAI's approval.

CONCLUSION AND SUGGESTIONS

GM crops represent a significant advancement in agricultural research and may provide answers to pressing worldwide problems such as declining agricultural productivity, environmental problems, and food shortages. Crops with enhanced traits, like insect resistance, drought tolerance, and higher nutritional value, can be produced with the help of genetically modified organisms. These advantages, which include increased farm yields, a decreased need for chemical pesticides, and more ecologically friendly farming practices, have already been clearly demonstrated in nations that have adopted GM crops. This can be observed in the instance of Bt cotton in India, where farmers report higher yields and reduced costs as a result of using fewer pesticides. Despite the obvious advantages, India has been hesitant to adopt GM crops completely, following a cautious and strictly controlled process. This cautious stance is influenced by worries about biosafety, environmental effects, and the moral aspects of genetic changes. Public doubts, slow policy decisions, and disagreement among scientists, politicians, and community groups have limited the approval of GM crops in the country. Although being careful is important to ensure responsible development, it's also important to consider scientific data and the urgent need to provide enough food for the nation's growing population. With the country's increasing population and limited farmland, improving agricultural efficiency is more important than ever. If managed properly and monitored transparently, GM crops can be a key part of achieving these goals. GM crops should be part of broader strategies for sustainable farming, including blends with organic practices, methods to manage pests without chemicals, and techniques to save water. Health risks linked to GM crops need to be thoroughly studied, however global research shows no proven harm when they are developed and used under strict safety guidelines. In conclusion, it is important to stay alert about possible risks, but India cannot ignore the significant potential of GM crops. Through balanced rules, informed public conversations, and strong scientific research, GM technology can become a valuable asset in India's efforts to ensure food security, protect the environment, and strengthen agriculture.

REFERENCES

1. Abdul Aziz, M., Brini, F., Rouached, H., & Masmoudi, K. (2022). Genetically engineered crops for sustainably enhanced food production systems. Frontiers in Plant Science, 13, 1027828. https://doi.org/10.3389/fpls.2022.1027828

2. Brookes, G., & Barfoot, P. (2020). Farm income and production impacts from the use of genetically modified (GM) crop technology 1996–2018. GM Crops & Food, 11(4), 242–261. https://doi.org/10.1080/21645698.2020.1779574

3. Ekici, K., & Sancak, Y. (2017). A perspective on genetically modified food crops. International Journal of Manures and Fertilizers, 5(2), 1–4. https://www.internationalscholarsjournals.com/articles/persp-ective-on-genetically-modified-food-crops.pdf

4. Gervais, J., Cocks, M., & Mermer, S. (2025). Bacillus thuringiensis (Bt) in genetically modified crops fact sheet. National Pesticide Information Center, Oregon State University Extension Services. http://npic.orst.edu/factsheets/bt-pip.html

5. Karalis, D. T., Karalis, T., Karalis, S., & Kleisiari, A. (2020). Genetically modified products: Perspectives and challenges. Cureus, 12(3), e7306. https://doi.org/10.7759/cureus.7306

6. Kathage, J., & Qaim, M. (2012). Economic impacts and impact dynamics of Bt (Bacillus thuringiensis) cotton in India. Proceedings of the National Academy of Sciences, 109(29), 11652–11656. https://doi.org/10.1073/pnas. 1203647109

7. Ngongolo, K., & Mmbando, G. S. (2025). Necessities, environmental impact, and ecological sustainability of genetically modified (GM) crops. Discover Agriculture, 3, 29. https://doi.org/10.1007/s44279-025-00180-0

8. Noack, F., Engist, D., Gantois, J., Gaur, V., Hyjazie, B. F., Larsen, A., M'Gonigle, L. K., Missirian, A., Qaim, M., Sargent, R. D., Souza-Rodrigues, E., & Kremen, C. (2024). Environmental impacts of genetically modified crops. Science, 385(6712), eado9340. https://doi.org/10.1126/science.ado9340

9. Raman, R. (2017). The impact of genetically modified (GM) crops in modern agriculture: A review. GM Crops & Food, 8(4), 195–208. https://doi.org/10.1080/21645698.2017.1413522

10. Sainger, M., Sainger, P., Chaudhary, D., Jaiwal, R., Singh, R., Dhankher, O., &Jaiwal, P. (2015). GM crops for developing world in the era of climate change: For increase of farmer's income, poverty alleviation, nutrition and health. In P. Jaiwal, R. Singh, & O. Dhankher (Eds.), Genetic manipulation in plants for mitigation of climate change (pp. 197–217). Springer. https://doi.org/10.1007/978-81-322-2662-8_11

11. Shetty, M., Chandan, K., & Krishna, H. (2017). Genetically modified crops: An overview. Journal of Pharmacognosy and Phytochemistry, 7(1), 2405–2410. http://researchgate.net/publication/323611876

12. Shukla, M., Al-Busaidi, K. T., Trivedi, M., & Tiwari, R. K. (2018). Status of research, regulations and challenges for genetically modified crops in India. GM Crops & Food, 9(4), 173–188. https://doi.org/10.1080/21645698.2018.1529518

13. Singh, P. (2021). Genetically modified crops in India: Politics, policies, and political economy. In S. N. Giri & A. Choudhary (Eds.), *Policy issues in genetically modified crops: A global perspective* (pp. 75–96). Academic Press.

14. Tabashnik, B. E., Fabrick, J. A., & Carrière, Y. (2023). Global patterns of insect resistance to transgenic Bt crops: The first 25 years. *Journal of Economic Entomology, 116*(2), 297–309. https://doi.org/10.1093/jee/toac183

15. Wang, P., Si, H., Li, C., Xu, Z., Guo, H., Jin, S., & Cheng, H. (2025). Plant genetic transformation: Achievements, current status and future prospects. Plant Biotechnology Journal, 23(6), 2034–2058. https://doi.org/10.1111/pbi.70028

16. World Population Prospects 2024: Summary results. (2024). United Nations, Department of Economic and Social Affairs, Population Division

17. Yuan, P., Usman, M., Liu, W., Adhikari, A., Zhang, C., Njiti, V., & Xia, Y. (2024). Advancements in plant gene editing technology: From construct design to enhanced transformation efficiency. Biotechnology Journal, 19(7), e202400457. https://doi.org/10.1002/biot.202400457