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GENETICALLY MODIFIED CROPS IN INDIA: POLITICS, PUBLIC PERCEPTION, ENVIRONMENT, AND HEALTH

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ABSTRACT

Genetically modified (GM) crops represent a significant scientific innovation aimed at addressing key agricultural challenges such as pest infestation, low productivity, nutritional deficiencies, and climate stress. In India, however, the adoption of GM crops has emerged as a highly contested issue that extends far beyond scientific risk assessment. This paper critically examines the multifaceted dimensions of GM crops in India by integrating political, social, environmental, and health perspectives. It analyzes how public perception, civil society activism, media narratives, and federal political dynamics interact with regulatory processes to shape policy outcomes. Through case studies of Bt cotton, Bt brinjal, and GM mustard, the study highlights the complex decision-making framework where scientific approvals are often mediated or overridden by political caution and public opposition. While GM crops offer potential environmental and health benefits, concerns related to biodiversity loss, seed sovereignty, corporate control, herbicide dependency, and long-term food safety continue to influence societal acceptance. The paper argues that the Indian experience underscores the need for transparent governance,

independent long-term research, effective science communication, and participatory policy mechanisms. A balanced and inclusive approach is essential to ensure that GM crop technologies, if adopted, align with ecological sustainability, public trust, and social equity in India.

KEYWORDS: Public Perception, Political opinion, Biosafety Regulation, Environmental Sustainability, Food Safety and Health, Seed Sovereignty.

1. INTRODUCTION

Genetically modified (GM) crops involve the deliberate alteration of plant genomes using modern biotechnological tools to introduce specific traits such as insect resistance, herbicide tolerance, improved yield potential, and enhanced nutritional quality (Singh et al., 2021). From a scientific standpoint, GM technology is designed to address key challenges in agriculture, including crop losses due to pests, nutritional deficiencies, and stresses arising from climate change. However, in the Indian context, GM crops are not perceived merely as neutral technological innovations but as interventions with profound social, economic, and political consequences.

In India, agriculture is closely linked to livelihoods, cultural practices, and rural identity, which makes any technological intervention in farming highly sensitive. GM crops are therefore evaluated not only for their agronomic performance but also for their implications for small and marginal farmers, seed sovereignty, and traditional knowledge systems. The introduction of GM seeds, often protected by intellectual property rights, has raised concerns about farmer dependency on external seed suppliers and the erosion of indigenous seed-saving practices. As a result, GM crops are frequently framed within larger debates on neoliberal agricultural policies, corporate influence, and national food sovereignty rather than within the narrower domain of scientific risk assessment.

Public perception further shapes the discourse on GM crops in India. Limited public understanding of genetic engineering, coupled with inadequate science communication by regulatory agencies, has contributed to widespread apprehension about potential health and environmental risks (Brossard et al., 2019). Genetic modification is often perceived as "unnatural" interference with nature, reinforcing ethical concerns related to the integrity of food systems and long-term human health (WHO, 2014). Civil society organizations, environmental activists, and sections of the media have amplified these concerns by

emphasizing uncertainties associated with allergenicity, gene flow, and biodiversity loss, even when regulatory bodies have declared certain GM crops to be biosafe.

Political ideologies play a decisive role in translating these perceptions into policy outcomes. Policymakers operate within a democratic framework where public opinion, farmer protests, and state-level opposition carry significant weight. This has resulted in instances where political decisions override scientific recommendations, as seen in the moratorium on Bt brinjal despite regulatory approval. Consequently, debates around GM crops in India are shaped as much by environmental ethics, social justice, and precautionary principles as by empirical biosafety data.

Thus, the Indian experience illustrates that GM crops are embedded within a broader socio-political landscape where science, politics, and public values intersect. Understanding GM crops in India therefore requires moving beyond laboratory assessments of safety to include questions of trust, governance, equity, and sustainability. This multidimensional framing explains why GM crop adoption in India remains cautious and contested, despite demonstrated scientific potential (Rao et al., 2025; Nature India, 2016).

2. Political Dimensions of GM Crops in India

2.1 GM Crops as a Policy and Governance Issue

The regulation of GM crops in India involves multiple institutions, including the Genetic Engineering Appraisal Committee (GEAC), Biotechnology Regulatory Authority of India (BRAI) and the Ministry of Environment, Forest and Climate Change. Although these bodies assess biosafety risks, political leadership often plays a decisive role in final approvals. This has resulted in policy uncertainty, delays, and moratoria, reflecting a precautionary and politically sensitive approach to agricultural biotechnologyas illustrated in Figure 1 (PRS Legislative Research, 2023; Rao et al., 2025).

2.2 Seed Sovereignty and Corporate Control

Concerns over seed sovereignty dominate political discourse on GM crops. The commercialization of Bt cotton led to fears that multinational corporations could monopolize seed markets through intellectual property rights, increasing farmer dependency and input costs. These concerns have been echoed by farmers' unions, activists, and political groups, framing GM crops as a threat to India's agrarian autonomy and traditional seed-saving practices (Peshin et al., 2021; Rao et al., 2025).

2.3 Federal Politics and Centre–State Conflicts

India's federal governance structure has played a critical role in shaping the trajectory of GM crop policy, often complicating decision-making and implementation. Although biosafety approval for GM crops is granted at the central level by expert regulatory bodies such as the Genetic Engineering Appraisal Committee (GEAC), agriculture is constitutionally a state subject. This division of authority has resulted in conflicts where state governments have opposed or refused the cultivation of GM crops approved by the Centre. The Bt brinjal episode is a prominent example, where several states publicly rejected its cultivation despite regulatory clearance, citing concerns over food safety, biodiversity, and farmer livelihoods.

These centre–state disagreements reflect the influence of regional political priorities, electoral considerations, and local public sentiment. State governments, being closer to farming communities and consumers, often respond more strongly to public protests and activist campaigns than to scientific risk assessments. Consequently, scientific recommendations are frequently subordinated to political caution, reinforcing a fragmented regulatory environment. This federal tension underscores the political sensitivity of GM crop governance in India and highlights the challenges of implementing a uniform biotechnology policy in a diverse and democratic country (Nature India, 2016; PRS Legislative Research, 2023).

3. Public Perception and Social Acceptance

3.1 Public Understanding and Risk Perception

Public perception of GM crops in India is shaped by limited scientific literacy and heightened sensitivity to perceived risks associated with food and health. Genetic modification is often viewed as an unnatural intervention in nature, generating fears about unforeseen environmental and health consequences. Unlike other agricultural technologies, GM crops directly affect food consumption, which amplifies public concern and emotional response. The absence of widespread public education initiatives and effective science communication by regulatory authorities has further deepened skepticism.

Risk perception is also influenced by historical experiences with environmental hazards and mistrust in institutional safeguards. As a result, even scientifically validated safety assessments are frequently questioned by the public. This precautionary mindset has contributed to strong resistance against GM food crops, particularly those intended for direct

human consumption, reinforcing the gap between scientific evidence and societal acceptance (Domingo & Bordonaba, 2011; Cui & Shoemaker, 2018; Rao et al., 2025).

3.2 Role of Civil Society and Media

Civil society organizations, environmental non-governmental organizations (NGOs), and activist networks have played a decisive role in shaping public opinion on GM crops in India. These groups have framed the GM debate around issues of environmental ethics, corporate dominance, farmer vulnerability, and long-term health risks. Campaigns opposing GM crops often emphasize the potential for biodiversity loss, gene contamination of native crop varieties, and ethical concerns related to manipulating living organisms.

The media has amplified these narratives by highlighting controversies, protests, and conflicting scientific claims, often without providing balanced or nuanced interpretations of biosafety data. In high-profile cases such as Bt brinjal and GM mustard, sustained civil society mobilization influenced political leaders to adopt precautionary or restrictive positions. Consequently, social acceptance of GM crops has been significantly shaped by advocacy-driven discourse rather than by institutional scientific consensus (Bhaskar & Ramesh Kumar, 2015; Nature India, 2016).

3.3 Trust Deficit in Regulatory Institutions

A persistent trust deficit between the public and regulatory institutions has emerged as a central challenge in GM crop governance. Limited transparency in field trials, restricted public access to biosafety data, and perceived conflicts of interest have fueled suspicion regarding the credibility of regulatory decisions. Many critics argue that risk assessments lack independence and long-term evaluation, particularly under Indian agro-ecological and dietary conditions.

This erosion of trust has led to increasing demands for independent safety studies, long-term health monitoring, public consultations, and mandatory labeling of GM foods. The absence of participatory governance mechanisms has further alienated stakeholders, reinforcing the perception that GM crop approvals prioritize technological advancement over public welfare. As a result, public mistrust continues to influence policy decisions and delay the acceptance of GM crops in India (Kumar & Rai, 2020; Rao et al., 2025).

4. Environmental Implications of GM Crops

4.1 Environmental Benefits

Advocates of GM crops argue that biotechnology offers important environmental advantages by reducing chemical pesticide use, enhancing crop productivity, and improving resource-use efficiency. Bt cotton in India initially demonstrated substantial reductions in insecticide application against bollworms, leading to lower environmental contamination and reduced exposure of farmers to toxic chemicals. Improved yields also contributed to better land-use efficiency, potentially reducing pressure on forests and natural ecosystems.

These benefits highlight the potential role of GM crops in promoting environmentally sustainable agriculture when integrated with appropriate agronomic practices. Supporters emphasize that GM technology, when responsibly managed, can complement integrated pest management strategies and contribute to climate-resilient farming systems (Subramanian, 2023; Choudhary & Gaur, 2010).

4.2 Ecological Risks and Biodiversity Concerns

Despite these potential benefits, critics emphasize significant ecological risks associated with GM crop cultivation (FAO, 2016). These include the possibility of gene flow from GM crops to wild relatives, leading to genetic contamination and erosion of indigenous crop diversity. India's status as a center of origin and diversity for crops such as brinjal and mustard intensifies these concerns, as unintended gene transfer could have irreversible ecological consequences.

Additionally, the widespread cultivation of GM crops has been linked to the evolution of pest resistance and the emergence of secondary pests, as observed in the later phases of Bt cotton cultivation. Such ecological feedback mechanisms challenge the long-term sustainability of GM crops and underscore the need for cautious, context-specific deployment (Rao et al., 2025).

4.3 Herbicide Tolerance and Chemical Dependency

Herbicide-tolerant GM crops, particularly GM mustard, have introduced a new dimension to the environmental debate. While these crops aim to simplify weed management and enhance productivity, critics argue that they may encourage excessive herbicide use, leading to soil degradation, water pollution, and harm to non-target organisms. The promotion of chemical-

dependent farming systems is seen as contradictory to India's broader goals of sustainable and ecologically balanced agriculture.

Environmental groups caution that increased herbicide use may disproportionately affect small farmers and agricultural laborers while undermining traditional weed management practices. These concerns have contributed to strong resistance against herbicide-tolerant crops and delayed their acceptance in India (Jayaraman, 2017; PRS Legislative Research, 2023).

5. Health and Food Safety Considerations

5.1 Potential Health Benefits

From a public health perspective, GM crops are promoted for their potential to reduce pesticide residues in food and address nutritional deficiencies. Biofortified crops such as Golden Rice, engineered to produce vitamin A, have been proposed as interventions to combat micronutrient deficiencies, particularly among children and vulnerable populations. Supporters argue that such crops can complement public health programs and improve nutritional outcomes in resource-limited settings (Cui & Shoemaker, 2018).

5.2 Health Risk Concerns

Despite regulatory assurances of safety, public concern regarding the long-term health effects of GM foods remains strong. Fears related to allergenicity, toxicity, and chronic health impacts persist, particularly in the absence of long-term feeding studies tailored to Indian dietary patterns. These concerns are amplified by uncertainties surrounding cumulative exposure and interactions with diverse food systems.

The precautionary principle has therefore become central to public discourse, with many stakeholders advocating for extensive long-term studies before the widespread introduction of GM food crops. This cautious approach reflects broader societal concerns about food safety and consumer protection (Bhaskar & Ramesh Kumar, 2015).

5.3 Ethics and Consumer Choice

Ethical considerations play a crucial role in shaping public attitudes toward GM foods. The demand for mandatory labeling reflects a broader insistence on informed consumer choice and transparency in food systems. Consumers increasingly view labeling as a fundamental

right, enabling them to make decisions aligned with their health beliefs, cultural values, and ethical preferences.

Transparency in GM crop development, approval, and commercialization is therefore seen as essential to restoring public trust. Ethical governance that prioritizes consumer autonomy and accountability is critical for improving social acceptance of GM technology in India (Cui & Shoemaker, 2018).

6. Indian Case Studies

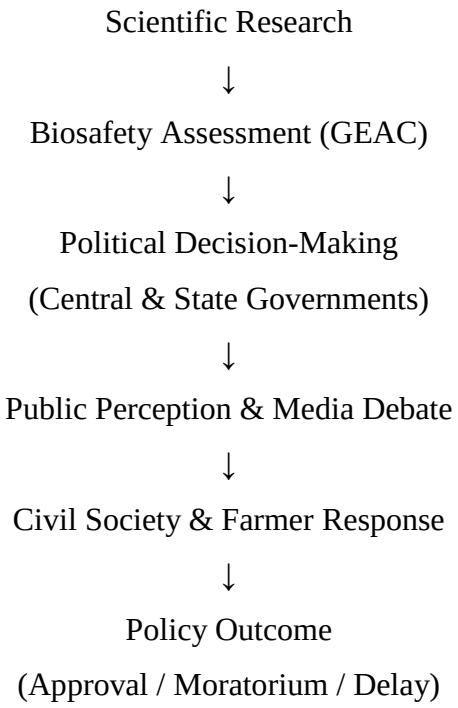

Figure 1: Multi-layered decision-making process for genetically modified crops in India.

6.1 Bt Cotton

Bt cotton, approved in 2002, remains the only GM crop commercially cultivated in India. It contributed to increased yields and reduced pesticide use in its initial years; however, the emergence of pest resistance, secondary pest outbreaks, and rising costs have highlighted the limitations of GM technology when used without integrated pest management (Kathage & Qaim, 2012; Subramanian, 2023; Peshin et al., 2021).

6.2 Bt Brinjal

Bt brinjal was developed to control fruit and shoot borer infestation and received regulatory approval in 2009. However, intense public opposition, political intervention, and concerns over biodiversity and food safety led to an indefinite moratorium in 2010. This case

exemplifies the dominance of public perception and political considerations over scientific clearance in India (Bhaskar & Ramesh Kumar, 2015; Nature India, 2016).

6.3 GM Mustard (DMH-11)

GM mustard, developed by Delhi University, aims to increase yield and reduce India's dependence on edible oil imports. Although it represents a public-sector innovation, concerns over herbicide tolerance, environmental safety, and long-term health impacts have delayed its commercial release, reflecting continued political and public caution (Jayaraman, 2017; PRS Legislative Research, 2023).

7. CONCLUSION

The debate over GM crops in India illustrates that biotechnology adoption is shaped by more than scientific evidence alone. Political dynamics, public perception, environmental ethics, and health concerns play a decisive role in shaping policy outcomes. India's experience underscores the need for transparent regulation, independent long-term research, effective science communication, and inclusive public dialogue to ensure that GM technology, if adopted, aligns with ecological sustainability and social justice.

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