

CONFLICTING PARADIGMS OF GENETICALLY MODIFIED ORGANISMS AND THEIR REGULATION IN INDIA

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ABSTRACT

Genetic engineering, the technology used to alter the genetic material of plants, animals and microorganisms, carries both promise and uncertainty in roughly equal measure. Genetically modified crops and foods remain the subject of sustained controversy touching food security, poverty alleviation, intellectual property, consumer choice, and human and environmental safety, a controversy that persists more than two decades after the first genetically modified products entered the market because neither their benefits nor their risks have been conclusively established. This paper examines the conflicting scientific and regulatory paradigms surrounding genetically modified organisms with particular reference to India, situating India's regulatory architecture against the international legal framework supplied by the Cartagena Protocol on Biosafety and the World Trade Organization's Agreement on Sanitary and Phytosanitary Measures, and against the contrasting regulatory models of the European Union and the United States. It traces the sustained judicial supervision genetically modified organisms have received in India through Aruna Rodrigues v. Union of India and the Supreme Court's 2024 split verdict in Gene Campaign v. Union of India concerning genetically modified mustard, and examines the statutory framework governing genetically modified food under the Food Safety and Standards Act, 2006 and the draft 2022 labelling regulations. The paper argues that India's approach, having produced only a single commercially approved genetically modified crop in over two decades despite sustained scientific and commercial pressure, reflects not regulatory failure but a considered, judicially reinforced precautionary posture that the country's food security imperatives make difficult, but not necessarily wrong, to sustain.

KEYWORDS: *Genetically Modified Organisms; Biosafety Regulation; Food Security; Precautionary Principle; Genetic Engineering Appraisal Committee*

1. INTRODUCTION

India is an agricultural economy of global significance, with agriculture and allied industry sustaining more than fifty-eight per cent of the population, particularly in rural areas, and contributing substantially to gross domestic product notwithstanding the sector's declining share of the economy as industrialisation proceeds.¹ The World Bank estimated that agriculture, forestry and fishery generated a gross value added of approximately Rs. 19.48 lakh crore in FY20, with agricultural and allied product exports reaching \$41.25 billion in FY21.² Against this economic backdrop, India's demographic trajectory sharpens the stakes of agricultural policy considerably: the United Nations projects a global population of 9.3 billion by 2050, and India was set to overtake China as the world's most populous country around 2026, while the 2021 Global Hunger Index ranked India 107th of 121 countries, a score denoting a serious level of hunger.³ India's food security accordingly depends on sustained growth in

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¹ India Brand Equity Foundation, Agriculture in India: Industry Overview, Market Size, Role in Development.

² Kekane Maruti Arjun, Indian Agriculture: Status, Importance and Role in Indian Economy, 4 Int'l J. Agric. & Food Sci. Tech. 343 (2013).

³ Global Hunger Index, India (2021); World Population Review, India Population 2023.

cereal, vegetable and fruit production sufficient to meet the demands of a still-growing population, a growth trajectory the country has pursued since the Green Revolution followed the lessons of the Bengal famine.

Genetic engineering, and the genetically modified organisms it produces, entered this policy landscape as a proposed next stage in that agricultural modernisation project. A genetically modified organism is a plant, animal, microbe or insect whose genetic material has been altered using recombinant technology in a manner that does not occur through natural mating or recombination, permitting the transfer of selected genes within or across species to produce what is also termed a transgenic organism. Genetically modified food, correspondingly, is food derived from or incorporating such organisms, typically engineered for improved pest or disease resistance, herbicide tolerance, or enhanced nutritional content. More than ten per cent of the world's cropland now grows genetically modified crops, with Argentina, Brazil, Canada, India and the United States together accounting for approximately ninety per cent of global cultivated area, concentrated principally in maize, cotton, soybean and canola.⁴ This paper examines the resulting conflict between agricultural and food-security imperatives favouring wider genetically modified adoption and the precautionary, rights-based and environmental objections that have made India's regulatory posture considerably more restrictive than the scale of scientific and commercial interest in the technology might otherwise predict, tracing that conflict through India's statutory framework, its international legal obligations, and, most consequentially, the sustained judicial supervision the technology has attracted before the Supreme Court.

2. THE SCIENTIFIC AND POLICY CASE FOR GENETICALLY MODIFIED ORGANISMS

Proponents of genetically modified organisms advance a cluster of related claims regarding their contribution to food security, environmental sustainability and farm income. Genetically modified crops can combine desirable traits extending shelf life or improving nutritional content, exemplified by rice biofortified with vitamin A, of the kind first commercially cultivated at scale in the Philippines using technology developed at the Swiss Federal Institute of Technology, Zurich, and capable in principle of addressing vitamin A deficiency across populations for whom rice constitutes a dietary staple.⁵ A comparable engineering logic has been applied to industrial applications: Enogen corn, incorporating a bacterial transgene that expresses alpha-amylase, converts corn starch to sugar more efficiently than conventional maize, reducing the energy and water required for ethanol production and illustrating that genetically modified applications extend beyond direct food consumption into the broader agricultural value chain. Insect-resistant varieties

⁴ Genetic Engineering Appraisal Committee, *Genetically Modified Crops: An Overview*.

⁵ M. Basu, *After India, Bangladesh & Vietnam, Now Philippines Harvests GM Golden Rice to Cure 'Hidden Hunger'*, *The Print* (Nov. 30, 2022).

incorporating genes from *Bacillus thuringiensis*, most prominently Bt cotton and Bt maize, have measurably reduced pesticide dependency; one widely cited analysis attributes an 8.3 per cent reduction in global pesticide spraying, equivalent to 775.4 million kilograms, to the adoption of genetically modified insect-resistant and herbicide-tolerant crops.⁶ Proponents further point to substantial farm-level economic gains, estimated at \$225.1 billion cumulatively between 1996 and 2018, divided roughly evenly between developing and developed country farmers, with seventy-two per cent of these gains attributed to yield and production increases rather than cost savings alone, alongside genetically modified organisms' emerging application in bioremediation, where engineered microbes have proved capable of degrading pesticide residues and industrial contaminants that native bacteria cannot effectively process, including the successful use of engineered *Escherichia coli* to degrade atrazine-contaminated soil.⁷ Genetically modified crops engineered for drought and salinity tolerance further extend cultivation into marginal land previously unsuitable for conventional agriculture, a capability of particular relevance to India's own climate-vulnerable agricultural regions. Norman Borlaug, the Nobel laureate associated with the Green Revolution, advocated for genetically modified food adoption during a 2005 visit to India specifically on food-security grounds, framing the technology as a necessary tool against persistent world hunger.⁸

3. THE PRECAUTIONARY CASE AGAINST GENETICALLY MODIFIED ORGANISMS

The case against unrestricted genetically modified adoption rests on a comparably serious set of concerns, only some of which have been scientifically resolved. A 2019-2020 Pew Research Center study across twenty countries found forty-eight per cent of respondents believed genetically modified food to be harmful, against only thirteen per cent who did not, with India recording fifty-eight per cent of respondents expressing safety concerns, among the highest surveyed, comparable to Russia at nearly seventy per cent, Poland at sixty-seven per cent and Italy at sixty-two per cent; by contrast, Sweden, the United States, Canada and India each recorded roughly a quarter of respondents expressing confidence in genetically modified food safety, with a substantial residual proportion in nearly every country surveyed indicating they lacked sufficient information to form a judgment at all, reaching fifty-one per

⁶ Graham Brookes & Peter Barfoot, *Environmental Impacts of Genetically Modified (GM) Crop Use 1996-2018: Impacts on Pesticide Use and Carbon Emissions*, 11(4) *GM Crops & Food* 215, 222 (2020).

⁷ Graham Brookes & Peter Barfoot, *GM Crop Technology Use 1996-2018: Farm Income and Production Impacts*, 11(4) *GM Crops & Food* 242, 248 (2020); Sharrel Rebello et al., *Bioengineered Microbes for Soil Health Restoration: Present Status and Future*, 12(2) *Bioengineered* 12845 (2021).

⁸ Sudha Rani M. et al., *History, Status and Impact of Genetically Modified Crops in India*, 6(5) *Int'l J. Chem. Stud.* 2735 (2018).

cent in Japan.⁹ This pattern of widespread public uncertainty, rather than confident opposition or confident endorsement, is itself analytically significant: it suggests that the genetically modified controversy persists less because the public has reached a settled adverse judgment than because neither government, industry nor independent science has yet supplied information sufficiently clear and trusted to resolve the underlying uncertainty.

Scientific bodies including the World Health Organization and the American Cancer Society maintain that no evidence presently links genetically modified food to cancer or allergic reaction in products currently on the market, while nonetheless acknowledging that ongoing research means the absence of demonstrated harm cannot be equated with an affirmative finding of safety.¹⁰ A related concern attaches to antibiotic resistance, since certain genetically modified crops carry genes conferring tolerance to specific pharmaceutical compounds, raising a theoretical, though the World Health Organization assesses as low-probability, risk of gene transfer to human gut microbiota, a risk regulators have nonetheless treated as sufficient to warrant specific safeguards for genetically modified food manufacturers. More concrete regulatory concern attaches to outcrossing, the risk of genetically modified genetic material contaminating conventional or organic crops through cross-pollination, a concern that has driven substantial regulatory divergence internationally: nineteen of the European Union's twenty-seven member states have chosen to ban genetically modified cultivation fully or partially, including Germany, France, Italy, Austria, Poland, Greece, Bulgaria, Denmark, Slovenia, Latvia, Hungary, Malta, Lithuania, the Netherlands, Luxembourg and Croatia, with Scotland, Wales, Northern Ireland and Belgium's French-speaking Wallonia region choosing to abstain from cultivation, notwithstanding the European Union's own general authorisation framework under Regulation 1829/2003 and Directive 2001/18/EC.¹¹ Romania, which initially permitted genetically modified cultivation, subsequently banned it after acceding to the European Union, illustrating that member states retain meaningful discretion to restrict cultivation even within a formally harmonised Union authorisation regime. Scientist Arpad Pusztai's contested but peer-reviewed finding that genetically modified potatoes damaged rat organ and immune function, and his subsequent suspension from the Scottish research institute where he had worked for thirty-five years, remains frequently cited by critics as evidence of institutional resistance to independent safety research within the genetically modified food industry, even as his findings have not been replicated to the satisfaction of the broader scientific community, and his study continues to be described by critics as the only genuinely independent safety assessment of a genetically modified crop

⁹ Des Keller, *Gene Revolution Turns 25: Why Does Europe Oppose GMOs?*, Progressive Farmer (2021), citing Pew Research Center international survey data.

¹⁰ American Cancer Society, *Common Questions About Diet, Activity, and Cancer Risk*.

¹¹ Regulation (EC) No. 1829/2003 of the European Parliament and of the Council, 2003 O.J. (L 268) 1; Directive 2001/18/EC of the European Parliament and of the Council, 2001 O.J. (L 106) 1; Mordor Intelligence LLP, *Europe Seed Market Report (2028 forecast)*.

published in a peer-reviewed journal, most other safety assessments having been conducted by the industry developing the crop in question.¹²

4. THE INTERNATIONAL LEGAL FRAMEWORK AND COMPARATIVE REGULATORY MODELS

International law supplies the backdrop against which India's domestic framework, examined in Part 5, must be understood. The Cartagena Protocol on Biosafety to the Convention on Biological Diversity, to which India is a party, establishes an advance informed agreement procedure governing the transboundary movement of living modified organisms, requiring exporting parties to notify and obtain consent from importing parties before the first intentional transboundary movement of such organisms intended for release into the environment, and embedding the precautionary approach directly into international biosafety governance.¹³ The World Trade Organization's Agreement on the Application of Sanitary and Phytosanitary Measures supplies a partially competing international discipline, requiring that any restriction on genetically modified imports be based on scientific risk assessment rather than unsubstantiated precaution, a tension the WTO Dispute Settlement Body confronted directly in *European Communities: Measures Affecting the Approval and Marketing of Biotech Products*, where a panel found the European Union's de facto moratorium on genetically modified approvals between 1998 and 2003 to be inconsistent with its SPS Agreement obligations insofar as it involved undue delay in completing approval procedures already underway, without thereby holding that a properly conducted, risk-based restriction on genetically modified organisms would itself violate WTO law.¹⁴ This distinction, between undue procedural delay and a substantively justified precautionary restriction, is doctrinally significant for assessing India's own regulatory posture, examined in Part 6, since a slow but genuinely deliberative approval process of the kind India has pursued for most genetically modified crops other than Bt cotton sits considerably closer to the SPS Agreement's tolerance than an indefinite, unreasoned moratorium would.

The European Union's approach, anchored in Regulation 1829/2003 and Directive 2001/18/EC, confines authorisation to a risk assessment of a genetically modified organism's effects on human health and the environment, expressly excluding socioeconomic considerations from the statutory test, a narrower authorisation criterion than India's own framework, examined below, formally contemplates.¹⁵ The United States, by contrast, applies a substantial-equivalence standard under which

¹² Anamarie Beluch, *The Moral Dilemma of Genetically Modified Foods (GMOs)* (2005) (unpublished student thesis, Fordham University).

¹³ Cartagena Protocol on Biosafety to the Convention on Biological Diversity, Jan. 29, 2000, 2226 U.N.T.S. 208.

¹⁴ *European Communities: Measures Affecting the Approval and Marketing of Biotech Products*, WT/DS291, 292, 293/R (WTO Panel Report, Sept. 29, 2006).

¹⁵ Regulation (EC) No. 1829/2003 of the European Parliament and of the Council, 2003 O.J. (L 268) 1.

genetically modified crops are regulated principally through existing food, drug and pesticide statutes administered by the Food and Drug Administration, the Department of Agriculture and the Environmental Protection Agency, treating a genetically modified product as subject to ordinary regulatory scrutiny unless it can be shown to differ materially in composition or risk profile from its conventional counterpart, a permissive default that has produced far broader genetically modified cultivation than either the European or Indian models permit. India's regulatory posture, traced in the following Part, occupies an intermediate position between these two poles, formally closer to the European precautionary model in structure but considerably slower in practical approval outcomes than either comparator, a divergence this paper attributes substantially to the sustained judicial supervision examined in Part 6.

5. INDIA'S REGULATORY ARCHITECTURE FOR GENETICALLY MODIFIED ORGANISMS

The Government of India permitted commercial cultivation of only one genetically modified crop, Bt cotton, in 2002, and the number of approved Bt cotton hybrid variants has expanded considerably since that initial approval; the Indian Council of Agricultural Research's long-term studies on Bt cotton found no adverse effect on soil microflora or animal health, and Bt cotton's insect-resistance trait has materially reduced losses from bollworm predation.¹⁶ No further genetically modified crop entered the Indian market for two decades after Bt cotton's approval, notwithstanding numerous varieties reportedly at various stages of development, a regulatory pattern this paper examines further in Part 6 through the lens of sustained public interest litigation before the Supreme Court.

The governing regulatory instrument is the Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms, Genetically Engineered Organisms or Cells, 1989, promulgated under the Environment (Protection) Act, 1986, which cover the full lifecycle of genetically modified organism development, research and development, field and clinical trials, deliberate and unintentional release, and import and export, administered jointly by the Department of Biotechnology under the Ministry of Science and Technology and the Ministry of Environment, Forest and Climate Change, together with the state governments.¹⁷ Six Competent Authorities operate under these Rules: the rDNA Advisory Committee, the Institutional Biosafety Committee, the Review Committee on Genetic Manipulation, the Genetic Engineering Appraisal Committee, the State Biotechnology Coordination Committee, and the District Level Committee, with the Genetic Engineering Appraisal Committee functioning as the principal approval

¹⁶ Sudha Rani M. et al., History, Status and Impact of Genetically Modified Crops in India, 6(5) Int'l J. Chem. Stud. 2735 (2018).

¹⁷ Vibha Ahuja, Regulation of Emerging Gene Technologies in India, 12 BMC Proc. 5 (2018).

authority for environmental release and commercial cultivation, a role that placed it at the centre of the litigation examined in Part 6.¹⁸

6. JUDICIAL SCRUTINY OF GENETICALLY MODIFIED REGULATION IN INDIA

India's genetically modified regulatory history since 2004 has been shaped as much by sustained Supreme Court supervision as by the statutory framework traced above. In *Aruna Rodrigues v. Union of India*, a public interest litigation filed under Article 32 of the Constitution, the petitioners sought a comprehensive protocol requiring rigorous biosafety examination before any release of genetically modified organisms into the environment, contending that existing approvals proceeded without adequate scientific safeguard.¹⁹ The Court's engagement with the petition proved unusually protracted and consequential: in September 2006, the Court directed the Genetic Engineering Appraisal Committee to withhold further approvals for genetically modified crops pending further instruction, and in May 2012, in a further order in the same proceeding, the Court, with the concurrence of all parties, constituted a Technical Expert Committee, chaired by the independent scientist P.M. Bhargava, to review and recommend appropriate risk-assessment sequencing for all genetically modified crops before environmental release.²⁰ The Technical Expert Committee's subsequent report characterised India's genetically modified regulatory system as being in a state of complete disarray and recommended, among other measures, a ten-year moratorium on field trials of herbicide-tolerant genetically modified crops, findings that have continued to shape both regulatory practice and subsequent litigation.²¹

This sustained judicial supervision reached its most consequential recent expression in *Gene Campaign v. Union of India*, decided by a two-judge bench of the Supreme Court on 23 July 2024 in a batch of petitions, filed by the non-governmental organisation Gene Campaign together with activist Aruna Rodrigues, challenging the Genetic Engineering Appraisal Committee's October 2022 approval of the environmental release of genetically modified mustard hybrid DMH-11 for seed production and testing.²² The litigation itself spanned two decades, the underlying writ petitions having been filed in 2004 and 2005, and traversed a series of interim developments worth tracing briefly: the Court permitted limited environmental release for testing purposes in 2006, the Technical Expert Committee's 2012 report generated further caution, and the Union Government voluntarily halted the release process in 2016 to seek broader public input before the Genetic Engineering

¹⁸ Id.

¹⁹ *Aruna Rodrigues v. Union of India*, Writ Petition (Civil) No. 260 of 2005 (India).

²⁰ *Aruna Rodrigues v. Union of India*, (2012) 5 S.C.C. 331 (India).

²¹ Centre for Civil Society, *The Science and the Law Behind the Genetically Modified (GM) Regulatory Logjam* (2022).

²² *Gene Campaign v. Union of India*, W.P.(C) No. 115 of 2004 (S.C., July 23, 2024) (India).

Appraisal Committee's eventual conditional approval in October 2022 reopened the controversy the Court finally addressed in 2024. Advocate Prashant Bhushan, appearing for the petitioners, argued that the Genetic Engineering Appraisal Committee had approved the mustard hybrid for environmental release without adequately engaging the Technical Expert Committee's specific recommendation that herbicide-tolerant genetically modified crops be banned pending further study, since DMH-11 itself possesses herbicide tolerance as an incidental trait of its hybridisation technique.

The Court delivered a split verdict: Justice B.V. Nagarathna held that the October 2022 approvals were vitiated, finding that the Genetic Engineering Appraisal Committee had failed adequately to consider the Technical Expert Committee's 2012 recommendations before approving the mustard hybrid, and emphasising that environmental protection could not be subordinated to developmental urgency, while Justice Sanjay Karol upheld the approval, accepting the government's position that a comprehensive, decade-long regulatory review process had already addressed the relevant biosafety concerns.²³ Both judges nonetheless agreed on two significant points of common ground: that judicial review of Genetic Engineering Appraisal Committee decisions is permissible notwithstanding the technical, scientific character of the underlying subject matter, rejecting any suggestion that biosafety approval decisions lie wholly beyond the competence of judicial scrutiny, and that the Union Government was required to formulate a comprehensive national policy on genetically modified crops, addressing specifically the treatment of herbicide-tolerant varieties, a policy no administration has yet produced notwithstanding the litigation's two-decade history. The resulting split left the legal status of genetically modified mustard's commercial release unresolved and referred the matter for resolution by a larger bench.²⁴ This outcome corrects any impression that genetically modified mustard's environmental safety has been judicially or scientifically settled in India; the split verdict instead confirms that the underlying regulatory and scientific dispute remains genuinely unresolved at the highest judicial level nearly two decades after the Aruna Rodrigues litigation first placed India's biosafety regime under sustained court supervision.

Read together, these decisions demonstrate a distinctive Indian pattern: rather than either a legislature-driven or agency-driven biosafety regime of the kind the European and American comparators in Part 4 respectively represent, India's genetically modified regulatory trajectory has been substantially co-authored by the judiciary, which has repeatedly intervened to demand more rigorous risk assessment, greater institutional independence in expert review, and, most recently, a coherent national policy the political branches have not themselves supplied. Whether this judicially driven caution reflects an appropriately precautionary response to genuine scientific uncertainty, or an institutional overreach into technical questions better

²³ Id.

²⁴ Id.

suited to expert regulatory judgment, remains contested, but its practical effect, a single commercially approved genetically modified crop over more than two decades, is not in doubt.

7. THE FOOD SAFETY AND FARMERS' RIGHTS DIMENSIONS

Genetically modified food entering the Indian market falls under a distinct statutory regime from the environmental release framework examined in Parts 5 and 6. Under Section 22 of the Food Safety and Standards Act, 2006, genetically modified food is unlawful in India until approved by the Food Safety and Standards Authority of India, which has released draft Food Safety and Standards (Genetically Modified Foods) Regulations, 2022 requiring prior clearance for the manufacture, import or marketing of food or ingredients derived from genetically modified organisms, and mandating that qualifying products bear the statement "contains genetically modified organisms" where genetically modified content constitutes one per cent or more of the product by composition.²⁵ The draft Regulations extend this labelling requirement beyond products with directly modified DNA to encompass food manufactured from genetically modified organisms without DNA alteration but incorporating genetically modified-derived chemicals, additives or processing aids, a comparatively expansive scope that, if brought into force, would bring India's labelling framework closer to the European Union's own comprehensive traceability requirements than to the more permissive American disclosure regime traced in Part 4.

Notwithstanding this formal prohibition, consumer advocacy groups note that genetically modified oils, including soybean and canola oil, have been imported into India for extended periods in the continued absence of any operative labelling framework, leaving consumers unable to make informed purchasing decisions regarding products already present in the domestic market; the Delhi High Court has separately directed the Food Safety and Standards Authority to consider a comparable labelling framework for artificially ripened produce, reflecting a broader judicial concern with consumer information deficits in India's food regulatory system that extends beyond genetically modified food specifically.²⁶ This gap between statutory prohibition and market reality is itself instructive: it demonstrates that a formally strict approval requirement, unaccompanied by the customs enforcement, laboratory testing and labelling infrastructure necessary to detect and act on non-compliant imports, can coexist for years with the very market penetration the prohibition was designed to prevent, a lesson with implications well beyond the genetically modified food context specifically.

²⁵ Food Safety and Standards Authority of India, Draft Food Safety and Standards (Genetically Modified Foods) Regulations, 2022 (India).

²⁶ Nupur Thapliyal, Consumers Must Know Whether Fruit or Vegetable Ripened Artificially: Delhi High Court Asks FSSAI to Frame Guidelines, LiveLaw.in (Nov. 4, 2022).

The farmers' rights dimension of genetically modified regulation raises distinct constitutional and human-rights concerns. A report by New York University's Center for Human Rights and Global Justice concluded that many smallholder farmers had been compelled into a system of industrialised, genetically modified-dependent agriculture that does not adequately support small farmers, leaving many increasingly indebted and, in the report's assessment, effectively deprived of secure livelihood in a manner implicating the right to gainful employment.²⁷ The Parliamentary Standing Committee on Science and Technology, Environment and Forests, in its report on genetically modified crops and their environmental impact, recommended that such crops be introduced only after critical scientific evaluation of their benefit and safety, and after restructuring the regulatory framework to ensure unbiased assessment, a recommendation broadly consistent with the judicially mandated caution traced in Part 6.²⁸

8. CONCLUSION AND RECOMMENDATIONS

More than two and a half decades after the introduction of genetically modified technology, genetically modified crops remain cultivated in only twenty-nine of one hundred and seventy-two countries, with ninety-one per cent of global genetically modified cultivated area concentrated in just five countries, Argentina, Brazil, Canada, India and the United States, while Japan, Israel, Russia, Malaysia and most of Europe continue to decline cultivation, a pattern suggesting the technology's global uptake has been considerably more contested and geographically concentrated than early industry projections anticipated. India's own experience, a single commercially approved crop sustained across more than two decades of litigation, expert review and unresolved policy formulation, exemplifies this broader global caution rather than standing as an outlier within it. This caution persists against a backdrop of genuine and worsening food insecurity that lends the underlying policy debate real urgency: the number of people experiencing hunger worldwide rose by 150 million between 2019 and 2021, from 618 million to 768 million, while those unable to afford a healthy diet rose by 112 million to reach 3.1 billion in 2020 alone, and the share of the global population experiencing moderate to severe food insecurity climbed from roughly a quarter before the pandemic to 29.3 per cent by 2021.²⁹ Genetically modified technology's proponents are right that these figures make the food-security case for the technology more, rather than less, urgent; its critics are equally right that urgency cannot itself substitute for the rigorous, independent safety evaluation that two decades of Indian litigation have consistently found wanting.

²⁷ New York University Center for Human Rights and Global Justice, *Every Thirty Minutes: Farmer Suicides, Human Rights, and the Agrarian Crisis in India* (2011).

²⁸ Parliamentary Standing Committee on Science and Technology, Environment and Forests, *Report on Genetically Modified Crops and Its Impact on Environment* (2017).

²⁹ *Global Nutrition Report 2022: Stronger Commitments for Greater Action*.

This paper's analysis supports several concrete recommendations. Parliament should legislate the comprehensive national policy on genetically modified crops that both judges in Gene Campaign called for but that the political branches have not yet supplied, resolving definitively the questions of herbicide-tolerant crop cultivation and Technical Expert Committee compliance that have generated two decades of continuing litigation. The 1989 Rules should be amended to embed a formal public participation and information-access mechanism, addressing the transparency deficit successive courts and expert committees have identified, consistent with the precautionary framework the Cartagena Protocol itself contemplates. The Food Safety and Standards Authority should finalise and bring into force the draft 2022 labelling regulations without further delay, closing the present gap between the Food Safety and Standards Act's formal prohibition on unapproved genetically modified food and the documented presence of unlabelled genetically modified-derived products already in the domestic market. Finally, any future expansion of genetically modified cultivation in India should proceed only alongside targeted protection for smallholder farmers of the kind the NYU report's findings suggest is presently lacking, ensuring that the technology's claimed benefits in yield and farm income are not achieved at the cost of the livelihood security of the very farmers the technology is meant to benefit. Substantial independent research funding, insulated from the commercial interests of genetically modified seed developers, remains essential to resolving the scientific uncertainty this paper has traced throughout, since only such research can finally supply the evidentiary basis on which India's courts, regulators and Parliament could responsibly move beyond the sustained precautionary posture the country has maintained since 2002.

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