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A Review on Genetically Modified Crops in Nigeria: Evolution, Regulation, Ethical Considerations, and Pathways for Adoption.

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Abstract

The rapid advancements in biotechnology have transformed agricultural systems worldwide with the introduction of genetically modified organisms (GMOs) and genetically modified (GM) crops at the forefront.The integration of genetically modified (GM) crops in Africa especially in Nigeria marks a significant transition in the country's agricultural sector. GM technology holds promise in boosting productivity, combating pests, reducing reliance on pesticides and enhancing food security.Despite the perceived advantages of GM crops, its adoption in Nigeria has spurred debates surrounding ethical concerns, public mistrust, socio-cultural resistance due to inadequate labelling and seed patenting which may threaten traditional farming practices, religious objections, corporate control of seed supply and limited public awareness. This review paper explores the benefits and drawbacks of GM technology and the need for stronger regulatory oversight, transparency, and public engagement to ensure the safe and equitable integration of GM crops. It also presents alternative strategies, including agro-ecological practices, biopesticides, and marker-assisted breeding, as complementary or culturally acceptable substitutes. By adopting a balanced approach that respects cultural and religious values while promoting scientific innovation, Nigeria can leverage biotechnology to achieve food security and agricultural sustainability. Strategies and recommendations include policy coherence, stakeholder engagement, capacity building, and the promotion of farmer rights, aiming to foster a socially inclusive and ethically responsible agricultural transformation.

Keywords: Genetically modified crops, food security, biosafety, public perception, ethical concerns, Nigeria

Introduction

The rapid advancement of biotechnology has significantly reshaped global agriculture, positioning genetically modified organisms (GMOs) and genetically modified (GM) crops at the forefront of modern food systems. These innovations have enabled scientists to enhance crop performance through gene transfer techniques that introduce traits such as pest resistance, drought tolerance, and improved nutritional content (Gbadegesin *et al.,* 2024). As countries continue to grapple with the challenges of food security, population growth, and environmental sustainability, GM crops have gained increasing attention as a viable solution.

Nigeria, as Africa's most populous country, is no exception. It faces persistent agricultural and nutritional challenges, including low yields, pest-related crop losses, climate variability, and a growing demand for food. In response, the Nigerian government and scientific community have gradually embraced GM technology, seeking to improve crop productivity and reduce the burden of food insecurity (Ajibade*et al.,* 2025). Since the first commercial release of GM crops globally in the 1990s, Nigeria has made significant strides, including the development of regulatory frameworks such as the National Biosafety Management Agency (NBMA) Act of 2015, which governs the safe application of biotechnology within the country (NBMA, 2017).

Despite these advancements, the path toward widespread adoption of GM crops in Nigeria remains complex and controversial. Key concerns include the potential risks to environmental biodiversity, long-term human health, seed sovereignty, and the cultural and religious values that influence public attitudes towards genetic modification. Additionally, misinformation, lack of transparency in food labelling, and inadequate stakeholder engagement have contributed to public skepticism and resistance (NABDA, 2021; Amedua *et al.,* 2025).

This paper critically examines the evolution of GM crops in Nigeria, their regulatory context, the scientific and socio-economic benefits they offer, and the ethical dilemmas they raise. It also explores the cultural and religious factors shaping public perception and outlines strategies to ensure that the integration of GM technology aligns with Nigeria's socio-economic realities and ethical standards.

2. Overview of GMOs and GM Crops

Genetically modified organisms (GMOs) are organisms (plants, animals, or microorganisms) whose genetic material has been altered in a way that does not occur naturally through mating or natural recombination. This process is typically achieved using modern biotechnology techniques such as recombinant DNA technology or gene editing (WHO, 2014). These technologies allow for the precise introduction of genes from one species into another, creating new traits that improve yield, pest resistance, or stress tolerance.

Genetically modified (GM) crops, a subset of GMOs, are specifically engineered for agricultural purposes. According to the International Service for the Acquisition of Agri-biotech Applications (ISAAA, 2023), a GM crop is a plant that carries a novel combination of genetic material introduced through biotechnological techniques. Unlike traditional breeding techniques, where traits are transferred between related species over generations, GM technology allows for targeted gene transfer across unrelated species, thereby accelerating the development of desirable traits. For example, a gene responsible for insect resistance from the bacterium *Bacillus thuringiensis* (Bt) can be inserted into crops such as maize or cowpea, enabling the plant to produce a protein that repels specific pests.

Although all cultivated crops have been genetically altered over time through domestication and selective breeding, GM crops represent a more rapid and controlled form of modification. This distinction is central to ongoing debates about their safety, efficacy, and societal impact. Advocates argue that GM crops offer solutions to critical agricultural problems, while critics raise concerns about ethical implications, long-term health effects, and environmental risks.

However, the purpose of introducing GM crops in Nigeria is part of a broader effort to modernize agriculture, combat food insecurity, and reduce reliance on chemical inputs. However, their adoption remains subject to scientific, regulatory, ethical, and cultural scrutiny.

3. Evolution of GM Crop Adoption in Nigeria

The journey towards the adoption of genetically modified (GM) crops in Nigeria began in the early 2000s which encouraged the increasing global recognition of biotechnology's potential to enhance agricultural productivity and address food insecurity. In 2001, the Nigerian government, through the National Biotechnology Development Agency (NBRDA) now the National Biotechnology Research and Development Agency (NARDA) initiated national efforts to promote, commercialize, and regulate biotechnology (Jibril *et al.,* 2022). This marked the foundation for future policy actions, research partnerships, and regulatory frameworks.

A key milestone was reached in 2004 when Nigeria signed a Memorandum of Understanding (MoU) with the United States to support the development and adoption of GM crops (Olaniyan *et al.,* 2007). This collaboration provided technical assistance and institutional support for biotechnology research and capacity building. The momentum gained further traction in 2015 when the National Biosafety Management Agency (NBMA) Act was signed into law. This legislation formally established the NBMA as the national authority responsible for regulating GMOs, ensuring their safe application, and protecting human health and the environment (NBMA, 2017).

In 2019, Nigeria approved its first indigenous GM food crop; the pod borer-resistant (PBR) cowpea. Developed through a partnership involving the African Agricultural Technology Foundation (AATF), this variety was engineered to resist *Maruca vitrata*, a major insect pest responsible for significant yield losses in conventional cowpea cultivation (Alliance for Science, 2021). The cowpea was genetically modified by incorporating the cry1Ab gene from *Bacillus thuringiensis* (Bt), enabling the plant to produce a protein that is toxic to the insect pest. Field trials conducted across states such as Zaria, Kano, and Zamfara confirmed its efficacy and environmental safety (Jibril *et al.,* 2022).

The introduction of Bt cowpea represents a historic advancement in Nigeria's agricultural biotechnology landscape. It illustrates the potential of GM technology to reduce pesticide use, improve yields, and strengthen food security. However, it also brought to light some lingering concerns around public acceptance, regulatory capacity, seed control, and ethical considerations, all of which continue to shape the national dialogue on GM adoption.

4. Benefits of GM Crops in Nigeria

The adoption of genetically modified (GM) crops in Nigeria presents numerous opportunities to transform the agricultural sector by addressing long-standing challenges such as low productivity, food insecurity, and reliance on chemical inputs. The benefits of GM crops are multifaceted, spanning agronomic, economic, nutritional, and environmental dimensions.

4.1 Increased Agricultural Productivity

One of the most cited advantages of GM crops is their potential to significantly increase crop yield. Through genetic modifications, crops can be engineered to resist pests, tolerate drought, and thrive in low-fertile soil conditions that frequently hinder Nigerian farmers. For instance, the pod borer-resistant (Bt) cowpea enables farmers to avoid up to 80% yield losses caused by *Maruca vitrata,* a pest prevalent in traditional cowpea farming (Alliance for Science, 2021).

4.2 Reduced Dependence on Chemical Pesticides

Traditional farming in Nigeria often relies heavily on chemical pesticides, which pose environmental and health risks. GM crops like Bt cowpea are designed to produce insecticidal proteins that naturally deter pests, thereby reducing the need for pesticide application (Shan, 2024). This helps protect ecosystems, conserves beneficial insect populations, and minimizes farmers' exposure to hazardous substances.

4.3 Enhanced Food Security

With Nigeria's population projected to exceed 400 million by 2050, ensuring food security is paramount. GM crops contribute to food security by increasing the quantity, stability, and quality of food produced. Traits such as herbicide tolerance, drought resistance, and pest resistance help stabilize yields even under suboptimal conditions (Savita, 2025). Moreover, crops with longer shelf life and resistance to microbial spoilage help reduce post-harvest losses during transport and storage.

4.4 Nutritional Improvement

Genetic modification can be used to biofortify staple foods, enhancing their nutritional content. Examples from other countries, such as Golden Rice enriched with beta-carotene, shows how GM crops can help address micronutrient deficiencies, including vitamin A, iron, and zinc, such nutritional gaps are also common in Nigeria. Similar efforts can be made with locally relevant crops to combat malnutrition, particularly among vulnerable populations (Savita, 2025).

4.5 Economic Empowerment for Farmers

By improving yield stability and reducing input costs associated with pesticides, herbicides and fertilizers, GM crops can enhance profitability for smallholder farmers. With fewer pest outbreaks and better marketable produce, farmers are positioned to earn more from each harvest. This economic empowerment, when combined with access to training and fair seed pricing, has the potential to lift rural communities out of poverty and stimulate agricultural innovation. The strategic integration of GM crops into Nigeria's agricultural systems offers a promising path toward enhanced food production, environmental sustainability, and rural development. However, these benefits can only be fully realized if accompanied by robust regulatory oversight, farmer education, and public trust.

5. Challenges and Limitations of GM Crops in Nigeria

While genetically modified (GM) crops present notable benefits for Nigeria's agriculture and food security, their adoption is accompanied by a series of complex challenges. These challenges span environmental risks, socio-economic inequities, regulatory limitations, and deeply rooted ethical and cultural objections.

5.1 Environmental Risks and Biodiversity Concerns

Although GM crops like Bt cowpea reduce the need for chemical pesticides, they may also contribute to the emergence of "superweeds" and resistant insect populations due to prolonged exposure to specific genetic traits (Ajibade *et al.,* 2025). Such resistance can prompt the reintroduction of more aggressive chemical inputs, thus negating earlier environmental gains. Furthermore, there are concerns about potential gene flow from GM crops to wild relatives or non-GM varieties, which could impact biodiversity and disrupt native ecosystems.

5.2 Human Health Concerns

Although regulatory agencies such as the World Health Organization (WHO) and the U.S. Food and Drug Administration have generally declared and approved GM foods safe, skepticism persists regarding long-term health effects especially in contexts where food safety monitoring is inconsistent. Some public health advocates argue that potential allergenicity and unknown side effects have not been sufficiently studied in African populations, where dietary and genetic contexts may differ (Gbadegesin *et al.,* 2024).

5.3 Seed Monopolization and Economic Dependency

Most GM seeds are patented by multinational biotechnology companies, which restrict farmers from saving or replanting them without a license. This practice introduces dependency on commercial seed suppliers and undermines traditional seed-saving customs that are vital to Nigerian smallholder farmers (Ajibade *et al.,* 2025). This dependency may lead to increased production costs and reduced autonomy for local communities, particularly in rural areas with limited access to credit or subsidies.

5.4 Ethical and Cultural Opposition

In many Nigerian communities, especially those with strong religious or indigenous beliefs, GM technology is viewed as tampering with divine creation or natural order. This perception has led to resistance from religious groups and traditional farmers who view the practice as incompatible with their cultural identity (Ogunwola *et al.,* 2020). Moreover, the replacement of indigenous seeds with modified varieties raises fears about the loss of cultural heritage and agricultural sovereignty.

5.5 Inadequate Public Awareness and Misinformation

A major impediment to GM crop adoption in Nigeria is the widespread lack of understanding among the public. Limited science communication, absence of mandatory GMO labelling on food products, and misinformation especially via social media have deepened public mistrust (NABDA, 2021). Without transparent engagement and access to accurate information, many Nigerians remain unconvinced about the safety and relevance of GM foods.

5.6 Regulatory Gaps

While Nigeria has established a national biosafety framework through the NBMA, concerns remain about regulatory independence, enforcement capacity, and stakeholder inclusion. Critics have pointed to potential conflicts of interest within the NBMA's governing board, and a lack of strict liability mechanisms to ensure accountability in cases of environmental or health harm (Premium Times, 2020). Despite their technical promise, GM crops in Nigeria face multidimensional obstacles that must be addressed through careful policy design, ethical dialogue, and participatory governance.

6. Policy and Regulatory Framework for GM Crops in Nigeria

Nigeria has established one of the most comprehensive biosafety regulatory systems in Africa to manage the introduction, use, and commercialization of genetically modified organisms (GMOs). This framework is designed to balance innovation in biotechnology with the protection of human health, the environment, and national sovereignty.

6.1 The National Biosafety Management Agency (NBMA) Act

The cornerstone of Nigeria's biosafety governance is the National Biosafety Management Agency (NBMA) Act, enacted in 2015 and amended in 2019. The Act formally created the NBMA, empowering it to oversee the regulation of GMOs, including their production, importation, handling, transport, use, and disposal (NBMA, 2017). The amendment broadened the agency's mandate to include emerging biotechnologies such as gene editing, synthetic biology, and gene drives.

The Act emphasizes the precautionary principle and seeks to ensure that all GMO activities in Nigeria are safe, traceable, and compliant with international obligations, including the Cartagena Protocol on Biosafety.

6.2 Other National Policies Supporting GMO Regulation

Several national policies work in tandem with the NBMA Act to support biotechnology governance such as;

1. National Biotechnology Policy – Guides research, development, and application of biotechnology across all sectors (NBMA, 2017).
2. National Environmental Policy – This policy identifies key sectors requiring integration of environmental concerns and sustainability with development. It presents specific guidelines for achieving sustainable development in the following fourteen sectors of Nigeria's economy: Human Population; Land Use and Soil Conservation; Water Resources Management; Biodiversity Conservation including Forestry, Wildlife, and Protected Natural Areas; Marine and Coastal Area Resources; Sanitation and Waste Management; Toxic and Hazardous Substances; Mining and Mineral Resources; Agricultural Chemicals; Energy Production; Air Pollution; Noise in the Working Environment; Settlements; Recreational Space, Green Belts, Monuments, and Cultural Property (NBMA, 2017).
3. National Agricultural Policy – Seeks to work with stakeholders to build an agricultural business economy capable of delivering sustained prosperity by meeting domestic food security goals, generating exports, and supporting sustainable income and job growth (NBMA, 2017).
4. National Policy on Health: To strengthen the national health system such that it will be able to provide effective, efficient, quality, accessible, and affordable health services that will improve the health status of Nigerians through the achievement of the health-related Sustainable Development Goals (SDGs) (NBMA, 2017).
5. National Policy on Science and Technology: To build a strong Science, Technology, and Innovation capability and capacity needed to evolve a modern economy (NBMA, 2017).
6. National Policy on Trade: To encourage the production and distribution of goods and services to satisfy domestic and international markets for the purpose of achieving and accelerating economic growth and development (NBMA, 2017).

These policies reinforce the legal and institutional structures required to manage GM crop development while addressing biosafety, trade, and socio-economic concerns.

6.3 Institutional Stakeholders and Roles

While the NBMA is the lead regulatory body, other government ministries, departments, and agencies contribute to biosafety oversight and they include:

1. Federal Ministry of Environment (FME).

The FME serves as the parent ministry of the NBMA and is responsible for developing and implementing environmental policies, including those related to biosafety. It ensures that biotechnology activities do not adversely affect the environment (FME).

2. Federal Ministry of Agriculture and Rural Development (FMARD).

FMARD focuses on enhancing agricultural productivity and sustainability. It collaborates with NBMA to ensure that genetically modified organisms (GMOs) used in agriculture are safe and beneficial to farmers and consumers (NBMA).

3. **Federal Ministry of Science and Technology (FMST).**

FMST oversees scientific research and technological development in Nigeria. It supports the advancement of biotechnology and works with NBMA to regulate and promote safe biotechnological innovations (NBMA).

4. **Federal Ministry of Industry, Trade and Investment (FMITI).**

FMITI is tasked with formulating policies that promote industrial growth and trade. It collaborates with NBMA to ensure that biotechnology products meet safety standards, thereby facilitating their acceptance in both local and international markets (FMITI).

5. **Federal Ministry of Health (FMoH).**

The FMoH ensures public health safety by evaluating the health implications of GMOs. It works alongside NBMA to assess and monitor the health risks associated with biotechnology products (NBMA).

6. **Nigeria Customs Service (NCS).**

NCS regulates the import and export of goods, including GMOs. It collaborates with NBMA to prevent the unauthorized entry of unapproved GMOs into Nigeria, thereby safeguarding the nation's biosafety (NCS).

7. **National Agency for Food and Drug Administration and Control (NAFDAC)**

NAFDAC is responsible for regulating and controlling the manufacture, importation, exportation, distribution, advertisement, sale, and use of food, drugs, and other products. It ensures that biotechnology-derived products are safe for consumption (NAFDAC).

8. **National Biotechnology Research and Development Agency (NBRDA).**

NBRDA promotes and coordinates biotechnology research and development in Nigeria. It works with NBMA to ensure that biotechnological innovations are safe and align with national development goals (NBRDA).

9. **Biotechnology Society of Nigeria (BSN).**

BSN is a professional body that advocates for the advancement of biotechnology in Nigeria. It collaborates with NBMA by providing expert opinions and promoting public awareness on biosafety issues.

10. **Representatives from Conservation NGOs and Organized Private Sector.**

These representatives provide insights and feedback on biosafety policies, ensuring that environmental and commercial interests are considered in the regulatory process (NBRDA).

The National Biosafety Management Agency along with these MDAs play a crucial role in ensuring the safe and responsible adoption of GM crops in Nigeria. By formulating biosafety policies and managing applications related to GMOs, the agency provides a structured framework for the regulation of biotechnology. The policies address public concerns about the safety and environmental impact of GM crops and, therefore building trust and encouraging their adoption.

6.4 Approved GM Crops in Nigeria.

Information obtained from the International Service for the Acquisition of Agri-biotech Applications (ISAAA, 2024) reveals that thirty-three (33) genetically modified (GM) crop approval events were carried out across five crop types in Nigeria

Table 1: List of Approved GM Crops in Nigeria.

S/N	GM Traits	Gene Source	Gene Introduced	Mode of Trait Introduction	Developer	Crop
1	Lepidopteran insect resistance, Antibiotic resistance, Visual marker	*Bacillus thuringiensi, E. coli.*	*Cry1Ac, nptII, aad, uidA, cry2Ab2.*	Microparticle bombardment of plant cells or tissue	Monsanto Company	Cotton.
2	Lepidopteran insect resistance	*Bacillus thuringiensis* subsp. *Kumamotoensis*	*cry1Ab* (truncated)	*Agrobacterium tumefaciens*-mediated plant transformation	African Agricultural Technology Foundation (AATF)	Cowpea
3	Drought stress tolerance	*Helianthus annuus*	*hahb-4*	Microparticle bombardment of plant cells or tissue	Bioceres S.A.	Wheat
4	Herbicide Tolerance (HT)	*Streptomyces viridochromogenes*	*pat*	Microparticle bombardment of plant cells or tissue	BASF	Soybean
5	Herbicide Tolerance (HT)	*Streptomyces viridochromogenes*	*pat*	Microparticle bombardment of plant cells or tissue	Bayer CropScience	Soybean
6	Glyphosate herbicide tolerance, Sulfonylurea herbicide tolerance	*Glycine max, Bacillus licheniformis*	*gm-hra, gat4601*	Microparticle bombardment of plant cells or tissue	DuPont (Pioneer Hi-Bred International Inc.)	Soybean
7	Glyphosate herbicide tolerance, Isoxaflutole herbicide tolerance	*Zea mays, Pseudomonas fluorescens* strain A32	*2mepsps, hppdPF W336*	Microparticle bombardment of plant cells or tissue	BASF	Soybean
8	Glufosinate herbicide tolerance, Glyphosate herbicide tolerance, Isoxaflutole herbicide tolerance	*Zeamays, Pseudomonas fluorescens* strain A32, *Streptomyces viridochromogenes*	*2mepsps, hppdPF W336, pat*	Conventional breeding – cross hybridization and selection involving transgenic donor(s)	Bayer Crop Science	Soybean

9	Glyphosate herbicide tolerance	*Agrobacterium tumefaciens* strain CP4	*Cp4 epsps (aroA:CP4)*	Microparticle bombardment of plant cells or tissue	Monsanto Company	Soybean
10	Lepidopteran insect resistance	*Bacillus thuringiensis* subsp. Kurstaki strain HD73	*Cry1Ac*	*Agrobacterium tumefaciens*-mediated plant transformation	Monsanto Company	Soybean
11	Glyphosate herbicide tolerance , Modified oil/fatty acid	*Glycine max,Agrobacterium tumefaciens* strain CP4	*fatb1-A, fad2-1A*	*Agrobacterium tumefaciens*-mediated plant transformation	Monsanto Company	Soybean
12	Glyphosate herbicide tolerance, Dicamba herbicide tolerance	*Stenotrophomonas maltophilia* strain DI-6, *Agrobacterium tumefaciens* strain CP4	*dmo, cp4 epsps*	*Agrobacterium tumefaciens*-mediated plant transformation	Monsanto Company	Soybean
13	Glyphosate herbicide tolerance, Modified oil/fatty acid	*Primula juliae, Neurospora crassa, Agrobacterium tumefaciens* strain CP4	*Pj.D6D, Nc.Fad3, cp4 epsps*	*Agrobacterium tumefaciens*-mediated plant transformation	Monsanto Company	Soybean
14	Glyphosate herbicide tolerance	*Agrobacterium tumefaciens* strain CP4	*Cp4 epsps (aroA:CP4)*	*Agrobacterium tumefaciens*-mediated plant transformation	Monsanto Company	Soybean
15	Multiple insect resistance, Mannose metabolism	*E. coli, Bacillus thuringiensis*	*pmi, ecry3.1Ab*	Developer *Agrobacterium tumefaciens*-mediated plant transformation	Syngenta	Maize
16	Glufosinate herbicide tolerance, Coleopteran insect resistance	*Streptomyces viridochromogenes, Bacillus thuringiensis*	*pat, cry34Ab1, cry35Ab1*	Developer *Agrobacterium tumefaciens*-mediated plant transformation in	Dow AgroSciences LLC and DuPont	Maize

17	Glufosinate herbicide tolerance, Lepidopteran insect resistance	*Streptomyces viridochromogenes, Bacillus thuringiensis* subsp. Kurstaki	*pat, cry1Ab*	Microparticle bombardment of plant cells or tissue	Syngenta	Maize
18	2,4-D herbicide tolerance	Synthetic form of the aad-1 gene from *Sphingobium herbicidovorans*	*aad-1*	Whiskers-mediated plant transformation	Dow AgroSciences LLC	Maize
19	Glyphosate herbicide tolerance, Lepidopteran insect resistance, Antibiotic resistance	*Bacillus thuringiensis* subsp. Kurstaki, *Ochrobactrum anthropi* strain LBAA, *Agrobacterium tumefaciens* strain CP4, *E. coli* Tn5 transposon	*cry1Ab, goxv247, cp4 epsps, nptII*	Microparticle bombardment of plant cells or tissue	Monsanto Company	Maize
20	Coleopteran insect resistance, Antibiotic resistance	*Bacillus thuringiensis* subsp. *Kumamotoensis*, *E. coli* Tn5 transposon	*cry3Bb1, nptII*	Micro particle bombardment of plant cells or tissue	Monsanto Company	Maize
21	Glyphosate herbicide tolerance, Coleopteran insect resistance, Lepidopteran insect resistance, Antibiotic resistance	*Bacillus thuringiensis* subsp. Kurstaki & *kumamotoensis, Agrobacterium tumefaciens* strain CP4, *E. coli* Tn5 transposon	*cry1Ab, cry3Bb1, cp4 epsps, nptII*	Conventional breeding – cross hybridization and selection involving transgenic donor(s)	Monsanto Company	Maize
22	Glyphosate herbicide tolerance	*Agrobacterium tumefaciens* strain CP4	*cp4 epsps (aroA:CP4)*	*Agrobacterium tumefaciens*-mediated plant transformation	Monsanto Company	Maize

23	Drought stress tolerance, Antibiotic resistance	*Bacillus subtilis, E. coli* Tn5 transposon	*cspB, nptII*	*Agrobacterium tumefaciens*-mediated plant transformation	Monsanto Company and BASF	Maize
24	Glyphosate herbicide tolerance, Coleopteran insect resistance	*Agrobacterium tumefaciens* strain CP4, *Bacillus thuringiensis* subsp. *kumamotoensis*	*cp4 epsps (aroA:CP4), cry3Bb*	*Agrobacterium tumefaciens*-mediated plant transformation	Monsanto Company	Maize
25	Lepidopteran insect resistance	*Bacillus thuringiensis* subsp. *Kumamotoensis*	*cry2Ab2, cry1A.105*	*Agrobacterium tumefaciens*-mediated plant transformation	Monsanto Company	Maize
26	Glyphosate herbicide tolerance, Lepidopteran insect resistance	*Agrobacterium tumefaciens* strain CP4, *Bacillus thuringiensis* subsp. *Kumamotoensis*	*cp4 epsps, cry1A.105, cry2Ab2*	Conventional breeding – cross hybridization and selection involving transgenic donor(s)	Monsanto Company	Maize
27	Glyphosate herbicide tolerance	*Agrobacterium tumefaciens* strain CP4	*Cp4 epsps*	Microparticle bombardment of plant cells or tissue	Monsanto Company	Maize
28	Not Available	Not Available	Not Available	Conventional breeding – cross hybridization and selection involving transgenic donor(s)	African Agricultural Technology Foundation (AATF)	Maize
29	Not Available	Not Available	Not Available	Conventional breeding – cross hybridization and selection involving transgenic donor(s)	-	-

30	Not Available	Not Available	Not Available	Conventional breeding – cross hybridization and selection involving transgenic donor(s)	-	-
31	Not Available	Not Available	Not Available	Conventional breeding – cross hybridization and selection involving transgenic donor(s)	-	-
32	Glufosinate herbicide tolerance, Antibiotic resistance	Synthetic form of pat gene derived from *Streptomyces viridochromogenes* strain Tu 494	*Pat (syn), bla*	Chemically mediated introduction into protoplasts and regeneration	-	-
33	Glufosinate herbicide tolerance, Lepidopteran insect resistance	Synthetic form of cry1F gene derived from *Bacillus thuringiensis* var. aizawai, *Streptomyces viridochromogenes*	*cry1Fa2, pat*	Microparticle bombardment of plant cells or tissue	-	-
34	Not Available	Not Available	Not Available	Conventional breeding – cross hybridization and selection involving transgenic donor(s)	African Agricultural Technology Foundation (AATF)	Maize
35	Not Available	Not Available	Not Available	Conventional breeding – cross hybridization and selection involving transgenic donor(s)	African Agricultural Technology Foundation (AATF)	Maize

36	Not Available	Not Available	Not Available	Conventional breeding – cross hybridization and selection involving transgenic donor(s)	African Agricultural Technology Foundation (AATF)	Maize
37	Glufosinate herbicide tolerance, Antibiotic resistance	Synthetic form of pat gene derived from *Streptomyces viridochromogenes* strain Tu 494	*Pat (syn), bla*	Chemically mediated introduction into protoplasts and regeneration	Bayer CropScience	Maize
38	Glufosinate herbicide tolerance, Lepidopteran insect resistance	Synthetic form of cry1F gene derived from *Bacillus thuringiensis* var. aizawai, *Streptomyces viridochromogenes*	*cry1Fa2, pat*	Microparticle bombardment of plant cells or tissue	Dow AgroSciences LLC and DuPont	Maize

6.5 Labelling and Consumer Protection

A key provision of the NBMA Act is the mandatory labelling of GM products. According to the law, all GMOs and GMO-derived products sold in Nigeria must be clearly labelled to ensure consumer choice and transparency (BusinessDay, 2023). However, enforcement remains inconsistent, raising concerns about informed consent and the right to food information (Amedua *et al.,* 2025).

6.6 Challenges in Regulatory Implementation

Despite the well-defined legal framework, Nigeria's biosafety regime faces several implementation challenges. These include insufficient funding for monitoring and inspection, limited public access to risk assessment reports, lack of transparency in decision-making, and perceived regulatory capture by pro-GMO entities (Premium Times, 2020). Additionally, the limited capacities for biosafety research and low public engagement have weakened the impact of the regulatory system on public perception and trust. While Nigeria has taken commendable steps toward establishing a biosafety regime that supports GM crop governance, ongoing efforts are needed to strengthen implementation, build public confidence, and ensure ethical compliance.

7. Ethical, Religious, and Cultural Considerations

The adoption of genetically modified (GM) crops in Nigeria is not only a scientific or agricultural issue but also an ethical and cultural challenge. In a country deeply rooted in religious beliefs and diverse traditions, biotechnology is often scrutinized through moral, spiritual, and socio-cultural lenses. These perspectives influence public perception, policy debates, and the level of acceptance or resistance among stakeholders.

7.1 Public Perception and Trust

Public attitudes toward GM crops in Nigeria remain ambivalent and are shaped by a mixture of hope, skepticism, and misinformation. While some segments of society acknowledge the potential of GM technology to address food insecurity and malnutrition, a large portion of the population remains cautious or opposed. Surveys reveal that around 70% of Nigerians support the labelling of GM foods, citing the right to informed choices (Ajibade *et al.,* 2025).

Mistrust is further fuelled by misinformation on social media and limited science communication by government agencies and research institutions. The absence of visible and credible public education initiatives has allowed fear-based narratives to dominate public discourse. As Hu and Chen (2025) reported, misinformation can significantly distort public perception, especially when cultural beliefs are not aligned with scientific explanations.

7.2 Religious Perspectives

Religious institutions in Nigeria particularly Christian and Islamic communities play a significant role in shaping ethical views. Some religious leaders argue that altering the genetic structure of organisms interferes with divine creation and violates natural laws (Ogunwola *et al.,* 2020). Terms such as "playing God" or "tampering with God's design" frequently surface in public discussions, leading to moral objections.However, other religious voices recognize the humanitarian value of GM crops, especially in addressing hunger and disease. These proponents argue that if GM technology can alleviate human suffering then it aligns with religious imperatives of compassion, stewardship, and responsibility.

7.3 Cultural Identity and Agricultural Sovereignty

Traditional farming practices are deeply intertwined with cultural identity and local knowledge systems in Nigeria. The introduction of patented GM seeds threatens these traditions by discouraging the centuries-old practices of seed saving, exchange, and communal ownership of agricultural resources. Many indigenous communities fear that replacing native crop varieties with genetically modified versions could erode biodiversity, undermine cultural practices, and increase dependence on foreign technologies (Adenle, 2014).Additionally, concerns about biopiracy, the exploitation of indigenous genetic resources by multinational corporations without fair compensation, further exacerbate public resistance. Organizations such as the Afenifere cultural group have voiced opposition, warning against the potential "colonization" of Nigeria's seed system (The Guardian Nigeria, 2023).

7.4 Intellectual Property and Ethical Justice

The ethical dilemma surrounding intellectual property rights is particularly significant. Patents on GM seeds prevent farmers from reusing them, imposing financial burdens and restricting their autonomy. While biotechnology companies argue that patents protect innovation while critics highlight the disproportionate impact on smallholder farmers who already face economic hardships (Hu & Chen, 2025).From a justice standpoint, the ability to produce and access food is a fundamental human right. Ethical concerns arise when innovation benefits are not equitably distributed or when farmers' traditional rights are overridden by corporate interests.

7.5 Consumer Rights and Transparency

Ethical concerns also extends to consumer rights;the NBMA Act mandates clear labelling of GM foods but enforcement has been inconsistent (Business Day, 2023). Lack of labelling of GM foodsinvadesconsumer's right to informed choices and raises concerns about food traceability and accountability in Nigeria. Ethical, religious, and cultural considerations are central to GM debate in Nigeria. A balanced approach that respects spiritual beliefs, cultural practices, and traditional livelihoods while promoting informed decision-making and regulatory transparency—is essential for ethical and socially acceptable biotechnology integration.

8. Strategies to Improve Adoption of GM Crops in Nigeria

The successful adoption of genetically modified (GM) crops in Nigeria depends not only on scientific advancements but also on inclusive governance, public trust, ethical safeguards, and institutional collaboration. To maximize the benefits of GM technology while minimizing resistance and ethical tensions, Nigeria must implement multidimensional strategies that address policy, communication, and capacity-building challenges.

8.1 Strengthening Government Involvement

Government leadership is essential for creating an enabling environment for GM crop adoption. The Nigerian government should prioritize:

- Policy coherence and enforcement: Biosafety laws must be consistently applied, including strict monitoring of GMO imports, mandatory labelling, and rigorous risk assessment.
- Public communication: Ministries and agencies such as the NBMA and Federal Ministry of Agriculture must engage the public through accessible and transparent communication campaigns. Educating citizens on the science, safety, and benefits of GMOs which will help to dispel misinformation and build trust (Alliance for Science, 2017).
- Regulatory reform: Ensuring independence and transparency within regulatory agencies can help prevent perceived or real conflicts of interest, particularly between regulators and biotech promoters (Premium Times, 2020).

8.2 Engaging Private Sector Stakeholders

Private biotechnology companies play a key role in research, seed production, and commercialization. However, their engagement must align with national development goals and ethical standards. Recommended strategies include:

- Public-private partnerships (PPPs): Collaboration between government, industry, and civil society can enhance innovation while ensuring accountability.
- Tailored seed solutions: Companies should develop GM varieties suited to Nigeria's diverse agro-ecological zones and smallholder farming systems.
- Training and capacity building: Firms can contribute by offering technical training to farmers on how to cultivate and manage GM crops responsibly (Kediso *et al.,* 2022).

8.3 Institutional Support and Academic Involvement

Universities and research institutions are critical to long-term capacity building and public engagement. Their roles should include:

- Localized research: Institutions should conduct region-specific trials to assess the performance, risks, and socio-economic impacts of GM crops.
- Biotechnology education: Including biotechnology and biosafety courses in academic curricula will prepare a skilled workforce to support the sector.
- Science communication: Academic experts must participate in public dialogue, media outreach, and community engagement to foster informed opinions (NEPAD, 2025).

8.4 Farmer-Centered Initiatives

Adoption strategies must prioritize smallholder farmers—the backbone of Nigeria's agricultural economy. Key actions include:

Subsidized access to GM seeds: To reduce cost barriers, the government and private sector can provide affordable seed packages and credit schemes.

Respect for traditional knowledge: Adoption should be voluntary and guided by local customs. Programs must integrate farmer feedback and preserve seed sovereignty.

Farmer cooperatives: Strengthening cooperatives can enhance farmers' bargaining power and collective capacity to negotiate with seed companies and policymakers.

8.5 Ethical and Religious Dialogue

To reduce opposition from religious and cultural groups, Nigeria must foster inclusive dialogue that respects moral values while clarifying scientific facts:

- Ethical advisory boards: Independent panels can assess the socio-cultural implications of GM crops and guide ethical decision-making (Princewill, 2023).
- Interfaith collaboration: Religious leaders should be engaged early in the policy process to ensure their perspectives are incorporated and disseminated to congregants.

Improving GM crop adoption in Nigeria requires coordinated action across government, industries, academia, and communities. By promoting transparency, ethical reflection, farmer empowerment, and localized innovation, Nigeria can navigate the complex terrain of biotechnology adoption with responsibility and inclusivity.

9. Alternatives and Complementary Solutions to GM Crops in Nigeria

Although genetically modified (GM) crops offer significant benefits, their adoption in Nigeria remains controversial due to ethical, cultural, economic, and ecological concerns. As a result, exploring complementary and alternative agricultural solutions is critical for a holistic and inclusive national food strategy. These alternatives aim to address similar challenges such as low productivity, pest pressure, and soil degradation without provoking the same degree of social or ethical resistance.

9.1 Promotion of Biofertilizers and Biopesticides

Biofertilizers and biopesticides, derived from naturally occurring microorganisms and organic materials, enhance soil fertility and pest control without the harmful environmental effects of synthetic chemicals or genetic manipulation. These eco-friendly inputs:

- Improve nutrient cycling and soil health.
- Pose minimal risks to non-target species and human health.
- Are compatible with organic and low-input farming systems (Sharma *et al.,* 2020).

Wider adoption of these inputs could help Nigerian farmers improve productivity sustainably while reducing dependency on synthetic agrochemicals and GM traits.

9.2 Agroecological Practices

Agroecology integrates ecological science with traditional farming knowledge to create resilient, biodiverse, and sustainable farming systems. Key principles include:

- Crop diversification and intercropping.
- Conservation agriculture (minimal tillage, cover crops).
- Natural pest management and soil regeneration (FAO, 2018).

Agroecology aligns with Nigeria's cultural values, emphasizing harmony with nature and community-based knowledge. It also builds resilience to climate change and reduces vulnerability to global input price shocks.

9.3 Improvement of Indigenous Crop Varieties

Rather than relying on genetically modified seeds, Nigeria can invest in the genetic improvement of local crops through conventional breeding and marker-assisted selection. These methods:

- Enhance traits such as drought tolerance, pest resistance, and yield potential.
- Maintain the integrity of native germplasm.
- Avoid many of the ethical concerns linked to transgenic technologies (Olaoye and Adebisi, 2021).

Developing and distributing improved local varieties can increase farmer acceptance and support biodiversity conservation.

9.4 Biobased Soil Enhancers and Composting

Organic soil amendments such as compost, microbial inoculants, and humic substances promote soil structure, water retention, and microbial activity. They serve as:

- Alternatives to synthetic fertilizers.
- Tools to rehabilitate degraded soils.
- Vehicles for sustainable nutrient management (Mahanty *et al.,* 2017).

Government and NGOs can support the widespread use of these amendments through training and demonstration programs.

9.5 Sustainable Input Innovation through Public-Private Collaboration

To foster innovation outside the GMO domain, partnerships between research institutions, government bodies, and private companies can focus on:

- Developing improved non-GMO seeds.
- Scaling up biopesticide and biofertilizer production.
- Supporting decentralized seed systems and extension services.

These partnerships should prioritize affordability, accessibility, and local ownership of agricultural technologies.

9.6 Farmer Education and Access to Alternatives

Providing farmers with knowledge, tools, and access to non-GMO technologies is essential. This includes:

- Training in composting, agroecology, and bio-input application.
- Demonstration plots showcasing performance of alternative practices.
- Development of rural innovation centres for hands-on learning.

By enabling farmers to make informed choices based on performance, sustainability, and cultural preferences, Nigeria can promote agricultural systems that are both productive and socially acceptable.

10. Conclusion and Recommendations

The adoption of genetically modified (GM) crops in Nigeria holds significant promise for enhancing food security, increasing agricultural productivity, and reducing the adverse effects of pests, diseases, and climate change. The approval of Bt cowpea and the establishment of biosafety regulatory mechanisms demonstrate Nigeria's commitment to embracing biotechnology as a tool for national development. With the support of institutions like the National Biosafety Management Agency (NBMA), the country has created a structured framework for evaluating and managing GM crop applications.

However, the integration of GM technology into Nigeria's agricultural system is not without challenges. Ethical concerns, cultural resistance, religious objections, weak regulatory enforcement, and misinformation continue to fuel skepticism. Economic concerns such as seed dependency, intellectual property issues, and the dominance of multinational corporations—have raised fears over the erosion of local agricultural sovereignty and seed rights. Additionally, inconsistent labelling practices have undermined consumer trust and violated the right to informed choice. To ensure a sustainable and ethically sound approach to GM crop adoption, the following recommendations are proposed:

10.1 Strengthen Regulatory Frameworks

Improve the independence, transparency, and enforcement capacity of biosafety institutions and establish clear liability provisions and ethical review boards to monitor GMOs' long-term impacts.

10.2 Expand Public Awareness and Education

Launch national education campaigns to provide balanced, evidence-based information about GM crops and promote science communication through local languages and community-based outreach.

10.3 Protect Farmer and Consumer Rights

Mandate full compliance with GMO labelling laws and Safeguard traditional seed-saving practices and support community seed banks to maintain seed sovereignty.

10.4 Encourage Ethical Dialogue

Involve religious leaders, traditional authorities, and cultural organizations in biotechnology discussions and create platforms for inclusive policy dialogue to address public concerns and build consensus.

10.5 Invest in Alternatives and Complementary Innovations

Support agroecology, bio-input development, and non-GMO crop improvement as culturally appropriate and sustainable pathways. Promote public-private partnerships to ensure affordable and accessible agricultural innovations.

10.6 Promote Inclusive Innovation

Ensure that GM crop development considers the needs of smallholder farmers, women, and marginalized communities. Support local research institutions in developing context-specific, socially acceptable biotechnologies.

In conclusion, GM crops have the potential to contribute meaningfully to Nigeria's agricultural transformation, but their success will depend on a multidimensional approach that balances technological innovation with ethical, cultural, and socio-economic considerations. Through participatory governance, transparency, and inclusive development strategies, Nigeria can harness the power of biotechnology while protecting the rights and values of its people.

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