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Full Length Research Paper

Navigating the genetically modified organisms crop debate: A comparative analysis of Nigeria and global perspectives

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Abstract

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This study provides a comprehensive analysis of the ongoing debate surrounding Genetically Modified Organisms (GMOs) in Nigeria, juxtaposed with global trends in their adoption. GMOs, designed to enhance traits such as pest resistance and drought tolerance, have become pivotal in addressing food security challenges. The findings reveal that while Nigeria is witnessing a gradual increase in GMO acceptance, particularly through the commercialisation of crops like Bt cotton, it still lags behind leading global adopters such as the United States and Brazil, where over 93% of major crops are genetically modified. In contrast, many European and African nations remain resistant to GMOs, driven by concerns over health risks, environmental impacts, and ethical considerations. The study identifies key stakeholders—including government policymakers, agricultural companies, and farmers—and examines how their perceptions influence food security, agricultural practices, and policy formulation in Nigeria. Ultimately, the research underscores the need for enhanced public awareness, improved regulatory frameworks, and innovative support systems to promote sustainable agricultural practices and ensure informed decision-making regarding GMO adoption in Nigeria.

Keywords: Food security; public perception; adoption challenges; nutritional benefits; environmental impact.

1. INTRODUCTION

Genetically modified organisms (GMOs) are organisms whose genetic material has been altered through genetic engineering techniques (Examples are presented in Figure 1). This process involves the insertion of genes from one organism into another to develop seeds (Figure 2 shows different types of seeds) with specific desirable traits, including drought tolerance, pest resistance, and enhanced nutrient density (Rock, 2019; Rostoks *et al.,* 2019; Sapturi *et al.,* 2019; Sendekie, 2020; Güneş, 2021; Yali, 2022). Despite the potential of GMOs to improve crop production and address critical issues of food security and nutrition, their acceptance remains contentious, particularly in Nigeria, where public perceptions diverge significantly from those in countries such as the United States and Brazil.

This study seeks to address a significant knowledge gap by investigating the factors that influence the acceptance of GMOs in Nigeria in comparison to other global regions.

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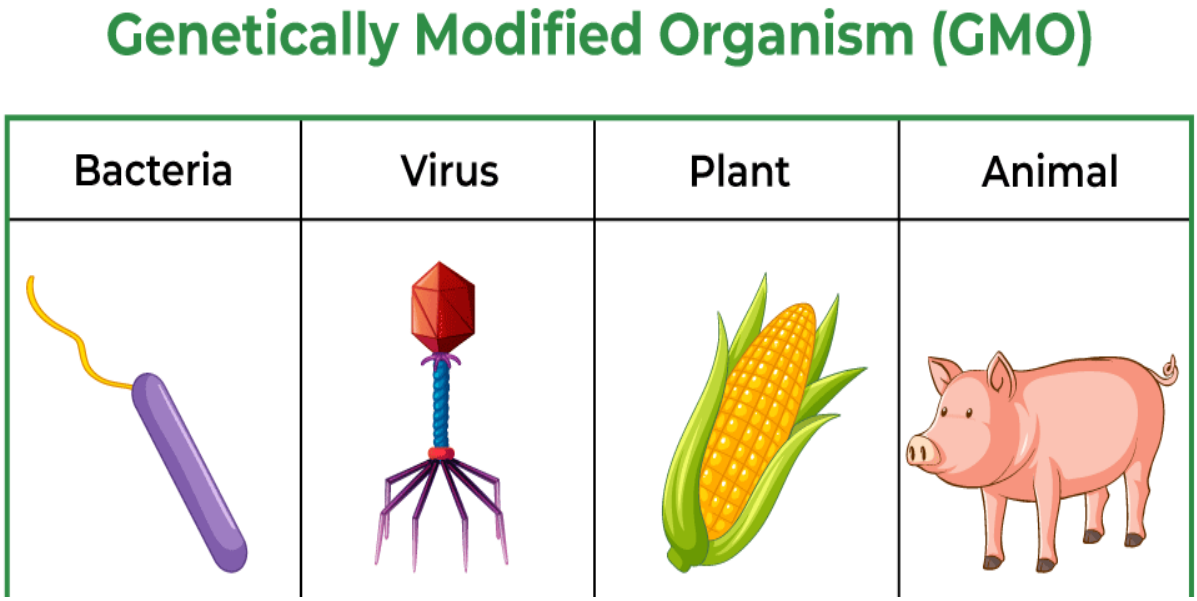

Figure 1: Genetically Modified Organisms, **Source:** Sharma et al. (2022).

GMO Seeds	Hybrid Seeds	Organic Seeds	Heirloom Seeds
GMO Seeds can produce only one generation of crops with similar characteristics	Hybrid seeds are also not capable of passing similar genetic traits from generation to generation	Organic seeds always breed true to the type i.e. produce the same crop after every harvest	Like organic seeds, heirloom seeds retain the same genetic traits across each generation
GMO seeds are created scientifically in a lab and some GMO seeds have pesticides like Bt engineered into the genetic structure of the seed	Hybrid seeds are produced by cross pollinating two cultivars of the similar plant for achieving the desired traits	Organic seeds are naturally produced. However, the certified organic seeds involve practicing controlled and completely organic methods of farming with no use of chemicals.	Heirloom seeds are produced by open-pollination carried out by pollinators like birds, bees and wind.
GMO seeds can not be saved	Just like GMO seeds, hybrid seeds can not be saved after harvest	Organic seeds can be saved after a harvest	Heirloom seeds can also be saved
GMO seeds may not fare any better when it comes to taste and flavours	In comparison to heirloom seeds, hybrid seeds can lack in certain traits	Since truly organic seeds are very rare now, most organic gardeners prefer using heirloom seeds	Heirloom seeds are far superior in taste, flavour and nutrition than other seeds

Figure 2: Features distinguishing different types of seeds, **Source:** Sendekie (2020).

Through a comprehensive analysis, this research aims to elucidate the complex interplay of scientific, ethical, environmental, and economic factors that collectively shape public perceptions and inform policy decisions regarding GMOs, thereby providing an informed understanding of the complex dynamics underlying GMO acceptance in Nigeria and beyond.

Empirical evidence suggests that commercial farmers in countries with high rates of GMO adoption experience increased yields and profitability (Oloo *et al.,* 2020; Brookes,

2022; Kavhiza *et al.,* 2022; Verma *et al.,* 2022). Proponents of GMOs argue that they are essential for meeting the growing global food demands, particularly in light of climate change challenges (Constance & Moseley, 2018; Leonelli, 2020; Doody, 2023). Conversely, significant opposition to GMOs persists in many African and European countries, driven by concerns about health risks, environmental impacts, and ethical considerations surrounding genetic modification (Ajoykumar *et al*., 2021; Gbadegesin *et al.,* 2022; Sadikiel Mmbando, 2024).

This introductory framework establishes a foundation for a critical analysis of the GMO debate in Nigeria, compared with international trends in GMO acceptance. The study undertakes a multifaceted examination, aiming to: (1) elucidate the underlying factors contributing to disparate levels of GMO acceptance; (2) evaluate the implications of these factors on food security, agricultural practices, and policy development; and (3) provide evidence-based recommendations for promoting sustainable agricultural practices in Nigeria, thereby informing policy and practice.

2. Global landscape of GMO adoption

Several countries have adopted GMOs, with the United States emerging as the foremost adopter. According to Wunderlich and Gatto (2015), the United States is the largest producer of GMO foods, contributing 73.1 million hectares of land and 40% of global conventional processed foods derived from GMO seeds. By 2016, over 93% of crops such as maize, soybean, and cotton were genetically modified (GM) (Brief, 2019).

Among the twenty-eight countries cultivating GMOs, Brazil ranks second in crop acreage, with 36.6 million hectares. This ranking has remained consistent since 2009, when Brazil experienced a 35.4% increase in the area planted with GMOs (Grossi-de-Sá *et al.,* 2016; Almeida *et al.,* 2017; Domínguez, 2022). Argentina, having begun studies in plant biotechnology in the 1980s, now sows over 24.9 million hectares of GM crops (Lewi & Vicién, 2020; de Cereales, 2021). Canada, a long-time user of GM crops, ranks fourth globally (Verma *et al.,* 2022).

In addition to these four major adopters, Africa is also perceived as attaining acknowledgement in the sphere of GMOs, although the concerns regarding its use remain a serious debate (Kedisso *et al.,* 2022; Gbadegesin *et al.,* 2022; Gbashi *et al.,* 2021). Public perception of GM crops in Africa is characterised by a diverse array of attitudes shaped by various socioeconomic factors and rich cultural traditions. Empirical studies have highlighted that public acceptance of GM crops in Africa is appropriately described by a rich tapestry of varied attitudes which can be influenced by a vast range of socioeconomic factors and cultural endowments. Being aware of these aspects is important for effective communication with the public and the management of policy measures. Further, the African countries' diverse regulatory measures create an intricate situation that influences not only the national agricultural practices but also cooperation processes, which can be from prohibition to careful permissive. The introduction of GM crops into African agriculture also raises significant ethical questions.

3. Reasons for the adoption of GMOs and products

In the past two decades, GMOs have been recognised as a real advancement in agricultural technology. As much as there have been controversies as to whether GMOs should continue to be used or not, there have been benefits that many farmers, policymakers, and scientists have advocated for. It implies that the alteration of plants and animals through the genetic engineering process can be very profitable, given the growing production of transgenic food products (Mathur *et al.,* 2017; kouSharma *et al*., 2022). Food crop producers are beginning to take advantage of great developments made with genetic engineering to improve agronomic, technological, and utilitarian characteristics.

a. Improved Yield

The global population's rapid approach to eight billion underscores the urgent need for efficient and productive agricultural practices. As highlighted by Verma *et al.* (2022), GMOs offer a viable solution to address escalating global food concerns, providing a more rapid and efficient means of enhancing crop productivity compared to traditional crop selection techniques. Genetic modification on the other hand provides a faster method of improving crops by incorporating certain genes that enhance production. For example, crops developed to express photosynthesis which has the potential of producing more biomass are likely to yield much better results (Kirst *et al.,* 2017; Simkin *et al*, 2019). This increase in crop yields enhances global food security and boosts farmers' profits, making GMOs a valuable tool in addressing global food challenges.

b. Pest and Diseases Resistance

GMO crops are specifically engineered to express genes that confer protection against both pests and diseases., synthesising proteins that act as insecticides and enhancing resistance against plant diseases. This dual benefit reduces the need for chemical pesticides, mitigating their severe environmental implications, including greenhouse gas emissions, and promoting ecosystem health through biodiversity and reducing chemical load on soil and water resources (Talakayala *et al.,* 2020). Further, Kouser *et al*. (2019) find that GMO seeds can help improve human health by lessening the pre-

valence of crop diseases which are caused by pests and pathogens, thereby improving food security and safety, hence reducing the incidence of food related diseases.

c. Mental Health

Agriculture is a time-consuming and highly demanding activity with farmers often facing stressful conditions, including market fluctuations, legal constraints, and unfavourable climate conditions, which can lead to anxiety, depression, and even suicidal tendencies (Riethmuller et al., 2023). Some of these pressures can be eased by adopting high-yield GMO seeds where there is increased confidence against crop failures due to pest attacks, weed competition, or drought, thereby reducing anxiety about crop loss and potentially enhancing mental health among farmers

d. Nutritional Benefits

Genetically modified (GM) foods have the potential to significantly improve the nutritional value of food, thereby aiding in the prevention and control of diseases such as diabetes, cancer, heart disease, and hypertension (Zhang *et al.,* 2016). Fortification with essential micronutrients (vitamins and minerals) and macronutrients (protein, carbohydrates, fats, and fiber) can have a great impact on health, particularly among children. For instance, vitamin A enrichment has greatly reduced the incidence of blindness. This is even more important in the developing nations where plant-based diets are the dominant food source. While the full benefits of GM foods may take decades to manifest, their positive effects on nutrition during formative years can have long-lasting, life-cycle benefits (Napier *et al.,* 2019).

4. Global landscape of GMOs' rejection

People and nations' experience of GMO rejection reveals cultural, political, and scientific drivers that influence public consciousness and policies. As GMOs are touted as a way of achieving higher and improved yields in agriculture and food security, resistance to their use has been noted due to health hazards, environmental effects and other technical issues. This rejection is often fueled by grassroots movements, government policies, and differing levels of scientific literacy, leading to a patchwork of acceptance and prohibition.

a. The European Union

The European Union (EU) stands out as a region that has not adopted GMO seeds, with some member countries enforcing stringent laws prohibiting GMO crops (Davison & Ammann, 2017; Karky & Perry, 2019; Turnbull *et al.,* 2021). The EU's cautious stance is driven by public concerns over the environmental and health impacts of GMOs, stringent regulatory frameworks, and a strong consumer preference for organic and non-GMO products.

b. Russia

Russia has taken a firm stance against the adoption of GMO seeds, passing a 2016 law that bans the cultivation and breeding of GM crops, allowing only scientific research (Turnbull *et al.,* 2021). According to Wegren *et al.,* (2016), the Russian government emphasised the importance of protecting the country's agricultural heritage and ensuring food security through traditional farming methods. This stance reflects both a precautionary approach to potential health and environmental risks and a desire to maintain control over domestic food production.

c. India

India has maintained an ambiguous stance on GMOs, permitting the production of bioengineered crop like Bt cotton but expressing reluctance towards approving other GMO food crops, such as Bt brinjal and GM mustard (Peshin *et al.,* 2021). This hesitation stems from concerns over the long-term environmental and socio-economic impacts, particularly on small farmers, as well as public scepticism and opposition from activist groups, prompting the government to exercise caution in its decision-making process.

d. Kenya

Kenya represents another case of cautious adoption of GMO technology. Although the Kenyan government lifted a ban on GMO imports in 2022 to address food security issues, significant resistance remains towards cultivating GMO crops (Catherine *et al.,* 2024). Environmental groups, farmers' associations, and segments of the public have raised concerns about the potential impact on local agriculture, biodiversity, and health, prompting the government to maintain a stringent regulatory framework that reflects a balanced approach between leveraging GMO technology for food security with addressing public concerns.

e. Peru

Peru has maintained an anti-GMO policy in agricultural production since 2011, introducing a 10-year ban on GMO importation, production, and use, which has since been extended (Dondanville & Dougherty, 2020). The government aims to conserve the country's biological diversity, particularly in the Andes and Amazon regions, while preserving indigenous agriculture and promoting organic farming practices to protect local germplasm purity (Zimmerer, 2023).

5. Reasons for non-adoption of GMO seeds and products

The potential consequences of GMO foods on human health have sparked intense debate, with several studies suggesting that the modifications employed in GMO preparation may have adverse effects on consumption (Arcieri, 2016; Levitsky, 2016; Singh *et al.,* 2022). Research has highlighted potential negative health impacts of GM foods, including instability and increased toxicity, with scholars warning of elevated concentrations of naturally occurring toxins, the development of novel toxicants, and enhanced capacity to accumulate environmental pollutants, such as pesticides and heavy metals (Blair & Regenstein, 2020).

Research has linked GMO foods to the emergence of new allergies, suggesting a potential causal relationship between GMO consumption and allergic reactions (Delaney *et al.,* 2018). The GM of food production has led to severe health consequences due to allergens, with bioengineered foods potentially containing allergens from other sources, thereby inadvertently exposing consumers to unknown allergens. This raises concerns about the adequacy of current food safety assessments and the management of food allergies, particularly among vulnerable populations such as children, highlighting a critical gap in public health risk management.

A significant yet often overlooked risk of GM foods is their potential to transfer genes that confer antibiotic resistance to pathogenic microbes, thereby aggravating the spread of diseases among humans. Antibiotic resistance genes exist in various foods and environmental sources, facilitating rapid assimilation (Jian *et al.,* 2021). When individuals consume GM plants, they may inadvertently ingest these genes, which can be taken up by microbes in their digestive systems. This may lead to the development of resistance to specific antibiotics, complicating treatment options for infections caused by these resistant bacteria. Consequently, the possibility of gene transfer is an important factor considered in evaluating applications for market approval or field studies of GMOs.

Besides the health concerns, many countries boycott GMOs for environmental reasons. citing concerns about the potential for GMO crops to cross-pollinate with natural crops, which could spread modified genes and disrupt ecosystems, adversely affecting soil health and microorganisms (Patton, 2022). Additionally, cultural and ethical beliefs regarding agriculture lead many to view GMOs as a threat to conventional farming practices, raising concerns about genetic manipulation and its potentially catastrophic effects on natural life forms.

Additionally, consumer awareness and market trends play a key role in determining the acceptability of GMO foods. Many societies prefer organic products, believing them to be healthier, and doctors often recommend organic foods for those with health issues. However, regulatory policies as well as legal barriers complicate the adoption of GMO seeds, as the lengthy approval process involving risk assessments and public consultations deters farmers (Vega Rodríguez *et al.,* 2022). Furthermore, concerns over patents, labeling, and environmental impacts continue to shape public perceptions of GMOs.

6. The GMOs debate in Nigeria: historical context and current status

Discussions on GMOs in Nigeria began in 2000, as the country explored biotechnology to enhance agricultural outcomes. The National Biotechnology Development Agency (NABDA) was established in 2001 to coordinate biotechnology development and regulation. In 2003, Nigeria approved its first Bt cotton crop under the Biosafety Agency to address pest challenges and increase yields (Gebretsadik & Kiflu, 2018; Olasoju *et al.,* 2018; GBARADA, 2021). However, large-scale adoption faced challenges such as public skepticism and regulatory and socio-economic issues.

Despite these challenges, acceptance of GMOs is growing in Nigeria, particularly through field trials and the commercialisation of crops like Bt cotton, cassava, and maize, which demonstrate potential for higher yields and pest resistance (Animasaun *et al.,* 2020). In 2021, Nigeria took a significant step by allowing Bt cotton in commercial markets, with more states adopting GMO technology (Akinbo *et al.,* 2021). The debate surrounding GMOs remains contentious; advocates argue that GMOs can improve food quality, increase crop yields, and reduce reliance on chemical pesticides. Conversely, critics express concerns about potential environmental impacts, human health risks, and economic challenges for smallholder farmers competing with larger producers (GBARADA, 2021; Okolo *et al.,* 2022). This dichotomy highlights the need for a balanced approach to biotechnology adoption, weighing its benefits against associated risks.

The Nigerian government has recently endorsed biotechnology as a means to enhance food production, with lobbyists urging the National Assembly to license GMOs to improve food security. There is also a growing call for educational programmes to inform the public about the merits and demerits of GMOs. Critics worry that adopting GMO seeds may degrade soil quality and create dependency on seed producers, rendering traditional seeds unviable. Such educational initiatives are crucial for fostering informed public perspectives on biotechnology.

Additionally, Nigeria has engaged in multilateral efforts to promote international cooperation in agricultural biotechnology research and development. Collaborations with the African Union and organisations like the International Service for the Acquisition of Agri-biotech Applications (ISAAA) have facilitated knowledge transfer and capacity building. These efforts indicate Nigeria's

Table 1: A structure comparing GMO adoption, policies, and public perceptions in Nigeria and other regions.

Region	GMO Adoption	Policies	Public Perception
Nigeria	Growing acceptance through field trials and commercialisation of crops like Bt cotton.	Government advocates for integration of GMOs for food security; emphasises public education.	Mixed; increasing support but significant skepticism remains. 70% support labeling of GMO products (Omoyajowo *et al.,* 2024).
United States	Widespread adoption; over 93% of crops like maize and soybean are GMOs.	Pro-GMO policies with minimal regulatory hurdles; strong support from agricultural companies.	Generally positive; seen as essential for meeting food demands and improving yields.
Brazil	Second-largest adopter of GMOs; consistent increase in acreage planted.	Supportive regulatory framework; promotes agricultural innovation.	Mostly positive; benefits recognised in terms of yield and pest resistance.
European Union	Minimal adoption; many countries prohibit GMO cultivation.	Stringent regulations; strong emphasis on safety and environmental protection.	Predominantly negative; public concerns over health and environmental impacts lead to rejection.
Russia	Complete ban on GMO cultivation; allows only scientific research.	Strict laws to protect agricultural heritage and ensure food security through traditional methods.	Negative; strong opposition based on health and environmental safety concerns.
India	Limited adoption; allows Bt cotton but hesitant on other crops.	Cautious approach due to environmental and socio-economic concerns.	Mixed; public skepticism and opposition from activist groups hinder broader acceptance.
Kenya	The recent lifting of the ban on GMO imports; cautious approach to cultivation.	Stringent regulatory framework balancing food security and public concerns.	Mixed; significant resistance remains despite government policy changes.
Peru	Anti-GMO policy with a long-standing ban on GMO production and importation.	Policies aimed at conserving biodiversity and promoting organic practices.	Negative; strong emphasis on preserving traditional agriculture and local germplasm.

commitment to utilising biotechnology to enhance agricultural performance, despite the sensitive nature of public acceptance and the policy and legal challenges that may arise in the future.

Table 1 summarises the key aspects of GMO adoption, policies, and public perceptions across different regions, highlighting both similarities and differences.

7. Key stakeholders and their perspectives on the adoption of GMOs in Nigeria

i.Government (Policymaker)

The Nigerian government recognises the importance of GMOs in enhancing food security and agricultural productivity. To address pressing challenges like climate change, pest resistance, and food scarcity, policymakers advocate for the integration of GMO crops. Studies have shown that smallholder farmers in Nigeria who used GM planting materials experienced reduced pesticide use and increased yields, highlighting the potential benefits of GMO adoption (Obi-Egbedi *et al.,* 2020). To ensure the safe and effective adoption of GMOs, governments and regulatory authorities emphasise the need for institutional mechanisms that maintain high product quality standards

and promote innovation in agriculture (Gbashi *et al.,* 2021). However, public perception remains a significant barrier to GMO adoption, underscoring the importance of educating and involving the public to address concerns and promote acceptance among stakeholders.

ii. Agricultural Companies and Seed Providers

Agricultural companies and seed providers in Nigeria welcome the concept of GMOs, believing it will drive innovation and increase production efficiency. They advocate for the commercialisation of GMO seeds, citing evidence that GMO crops can provide higher yields and require lower chemical inputs than traditional varieties (Zilberman *et al.,* 2018). However, these stakeholders face challenges, including bureaucratic risks and consumer resistance, as a significant portion of the population remains skeptical about GMOs (Ehirim *et al.,* 2020). In response, agricultural firms have shifted their focus toward education and outreach, engaging with farmers and consumers to address safety concerns and promote acceptance of GMOs.

iii. Farmers and Farming Communities

Farmers and farming communities in Nigeria hold diverse views on GMO availability, influenced by their experiences and understanding of the technology. While they perceive benefits such as improved crop yields, increased income, and enhanced resilience to drought and pests (Gbashi *et al.,* 2021), concerns persist regarding dependence on seed companies, loss of traditional practices, and potential health and environmental impacts. Furthermore, smallholder farmers face financial constraints, as GMO seeds and inputs can be up to 50% more expensive than conventional alternatives (Langyointuto, 2020), limiting their access and potentially aggravating social disparities. To address these challenges, stakeholders must facilitate open discussions, educate farming communities, and ensure that decision-making processes prioritize the needs of local agriculture and GMO technology adoption.

iv.. Environmental and Consumer Advocacy Groups

Environmental and consumer agencies in Nigeria are key stakeholders in the GMO adoption debate, consistently expressing concerns about potential social and ecological impacts. They advocate for stricter safety standards, transparency, and conservation of biological diversity, emphasising sustainable farming practices, and citing studies such as Jha *et al*. (2023) that highlight unfavourable GMO impacts, including soil destruction and negative effects on non-target organisms. Additionally, advocacy organisations emphasise the need for consumer choice and proper labeling of GMO foods, with 70% of Nigerian consumers supporting GM labeling requirements (Omoyajowo, *et al.,* 2024), and stress the importance of precaution, prioritising environmental and health values, while supporting research and surveillance to ensure the safe implementation of GMO technology.

8. RECOMMENDATIONS

To effectively navigate the complexities of the GMO debate in Nigeria and ensure a sustainable agricultural future, the following specific and actionable recommendations are proposed:

a. Enhanced public education and awareness campaigns:

Develop comprehensive educational programmes targeting farmers, consumers, and stakeholders with factual information about GMOs. Successful examples from countries like the United States and Brazil, which have implemented public outreach campaigns emphasising the safety and benefits of GMOs, can serve as models. These campaigns should focus on the scientific basis of genetic modifications, their advantages, disadvantages, and safety measures to ensure informed public discourse.

b. Strengthening regulatory frameworks:

Implement robust regulatory frameworks that ensure the safe development and commercialisation of GMO crops. This includes establishing transparent approval processes, sound risk assessments, and regular evaluations of GMO products in the market. Drawing lessons from the EU's stringent safety protocols while adapting them to local contexts can enhance public trust in GMO safety.

c. Promoting research and development:

Increase funding and support for research initiatives focused on the long-term effects of GMOs on health and the environment. Collaborations between government scientific organisations, research institutes, universities, and private sectors can lead to the development of safer and more sustainable GMO varieties tailored to local agricultural conditions. For instance, partnerships similar to those seen in Canada's agricultural biotechnology sector could be beneficial.

d. Supporting smallholder farmers:

Implement subsidy programmes or grant funding to assist smallholder farmers in accessing GMO seeds and necessary inputs. Initiatives similar to India's National Agricultural Market (e-NAM), which provides financial support and resources to farmers, can help reduce economic barriers and promote equitable access to biotechnology.

e. Encouraging stakeholder engagement:

Organise regular forums and meetings that facilitate dialogue among stakeholders, including government officials, agricultural companies, farmers, and consumer advocacy groups. Drawing inspiration from Brazil's multi-stakeholder approach to GMO discussions can help address concerns and share diverse perspectives, fostering a collaborative environment for GMO implementation.

f. Implementing clear labeling policies:

Introduce mandatory labeling requirements for GMO products to empower consumers with informed choices. Learning from successful labeling policies in advanced countries, Nigeria can establish transparent guidelines that allow consumers to make decisions based on their health preferences. This will not only alleviate concerns but also promote trust in food safety.

CONCLUSION

The ongoing debate surrounding GMOs in Nigeria highlights the critical need for a balanced approach that considers both the potential benefits of biotechnology and the public's concerns. By implementing actionable recommendations such as enhancing public education, strengthening regulatory frameworks, promoting research, supporting smallholder farmers, encouraging stakeholder engagement, and ensuring clear labeling, Nigeria can navigate the complexities of GMO adoption effectively. These strategies will not only improve food security and agricultural productivity but also ensure public trust and acceptance of GMOs. Ultimately, a collaborative effort among all stakeholders is essential to harness the full potential of biotechnology while addressing the socio-economic and environmental challenges facing Nigerian agriculture today.

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