Agricultural Biotechnology in Food Security and Poverty Alleviation in Kenya: Prospects, Challenges, and Strategic Pathways

Robert O. Recha[1*], Charles W. Recha[2] & Ibrahim O. Barasa[3]

[1]*Department of Agricultural Extension and Education, Egerton University, Kenya (recharobert@gmail.com)*

[2]*Department of Geography, Environment and Development Studies, Bomet University College, Kenya (cshika@yahoo.co.uk)*

[3]*Department of Education Foundations, Psychology and Management, Kaimosi Friends University College, Kenya (olungism@gmail.com)*

**Corresponding author: recharobert@gmail.com*

https://doi.org/10.62049/jkncu.v6i2.582

Abstract

Kenya, being a member state of the United Nations (UN), is committed to achieving the Sustainable Development Goals (SDGs). However, with an exponentially growing human population coupled with a decline in the performance of the agriculture sector over the last decade, achievement of the first two SDGs of ending poverty and hunger may seem difficult. Levels of austerity and food insecurity are rampant, especially in the Arid and Semi-Arid Lands (ASALs). Agricultural biotechnology offers a way out but comes with challenges. This study, therefore, explored the prospects, challenges, and strategic pathways associated with agricultural biotechnology. Desktop Research Design was adopted. Articles were sourced from multiple electronic databases. The study established that agricultural biotechnology has the potential to boost food productivity in the ASALs through the introduction of hardy but productive breeds of livestock and varieties of crops. Furthermore, the study established that agricultural biotechnology presents nutritional and environmental benefits. Besides the prospects, the study also identified possible health, economic, and environmental challenges associated with agricultural biotechnology, especially Genetically Modified Organisms (GMOs). The study, therefore, recommended that the National Biosafety Authority, with help from the ministries of Agriculture, Environment, and Health, should undertake independent and unbiased research on the potential prospects and challenges of agricultural biotechnology and disseminate the findings to Kenyans to enable them to make informed decisions on whether to embrace or reject agricultural biotechnology.

Keywords: Agricultural Biotechnology, Food Security, Poverty Alleviation, Prospects, Challenges, Strategic Pathways

Introduction

Demographic data from the United Nations Statistical Division (2024) The report revealed that the global human population was estimated to be 8.2 billion as of 2024 and is projected to grow to 9.7 billion by 2050 and peak at nearly 10.4 billion by the mid 2080's. With such an exponential growth in human population, coupled with pertinent issues like climate change, soil degradation, pollution, natural resource depletion, and many other emerging challenges directly facing agriculture, the sector is grappling to live up to the expectation of ending poverty and hunger. According to Food and Agriculture Organization [FAO] (2018)Over 800 million people globally are chronically hungry, with another 2 billion suffering from micronutrient-deficiency-related illnesses. Africa is facing a food crisis of unprecedented proportions. The situation has been further aggravated by the rippling effects of the COVID-19 pandemic, coupled with emerging global tensions such as the Russia-Ukraine war, whose aftermath has been felt in the disruption of the global food supply chain (FAO, 2023). Recent estimates show that almost 282 million Africans were malnourished in 2022, with 862 million being moderately food insecure and 342 million being considered severely food insecure (United Nations, 2024; FAO, 2023). In Kenya, approximately 1.9 million people, especially from the Arid Counties, are facing high acute food insecurity and need urgent attention based on the analysis report from the IPC-Acute Food Insecurity and Acute Malnutrition report conducted in 2024 (Government of Kenya, 2024).

Poverty is another menace so closely intertwined with food insecurity to an extent that the two almost seem intertwined and inseparable. Separate studies by Takahashi et al. (2020) and Giwu et al. (2024) affirmed that Climate change, conflicts and insecurity, low technological advancement, and high levels of illiteracy are some of the drivers of poverty, especially in the developing world. Kenya's economic growth seems to be fluctuating, with the Kenyan Shilling frequently depreciating against the USA dollar. Based on the Kenyan economic report conducted by the Kenya Institute for Public Policy Research and Analysis [KIPPRA](2020)The country's economy grew by 5.4 percent in the year 2019, which was a decrease of 0.9 percentage points from the year 2018. The report further revealed that despite the target to reduce the number of people living in absolute poverty from 46.0 percent to 28.0 percent, 36.1 percent of Kenyans are still living below the poverty line. With such stagnating economic growth coupled with high food insecurity and austerity, achievement of the Kenya Vision 2030 as well as the first two UN SDGs seems to be a mirage if proper interventions are not made, especially relating to the agricultural sector, which is considered to be the cornerstone of the country's economy. (Ouko et al., 2022).

In an effort to salvage the situation, the Kenyan government took a bold step towards promoting agricultural biotechnology on October 3rd, 2022, by lifting a decade-long ban on the open cultivation and importation of Genetically Modified Organisms (GMOs). This move was intended as a decisive, technocratic intervention to cushion the nation against a catastrophic, climate-induced famine and boost the economy by reviving the collapsing agricultural sector. Prior studies affirm that the practical application of biotechnology in agriculture is no longer a fantasy but rather a reality as it has become an integral component of the 21st century farming (Ruzzante et al., 2021; Shavanov et al., 2022; Tyczewska et al., 2023) This is partly attributed to the fact that modern biotechnological techniques such as cloning and genetic engineering that are employed in establishing Genetically Modified Organisms (GMOs) are comparatively fast, more specific and reliable in comparison to the traditional methods used in plant and livestock breeding (Eibl et al., 2021).

Despite the enthusiasm, the move to lift the ban on GMOs was met with much skepticism and resistance, evident through courtroom injunctions, civil society petitions, and deeply polarized public debates. This controversial antagonism between prompt state action, scientific ambition, and public anxiety perfectly encapsulates the sophisticated, high-stakes reality of the current state of agricultural biotechnology in Kenya. Olasoju et al. (2018) While proponents deem it an indispensable tool for survival through reduced production costs geared towards extricating small-holder farmers from poverty, critics have raised possible ecological, economic, and health concerns. The complex web of institutional, ethical, and socio-economic hurdles has ostensibly proven to be a stumbling block towards the transition of agricultural biotechnology from successful laboratory breakthroughs to the final adoption by farmers. (Serugo et al., 2024). In order to decipher how agricultural biotechnology can drive food security and poverty alleviation, a comprehensive study focusing on the exploration of the entire agricultural ecosystem encompassing socio-economic realities and legal frameworks governing biosafety needs to be undertaken. This study seeks to address this research gap.

The specific objectives are to: (i) document the prospects of agricultural biotechnology in addressing food insecurity and poverty alleviation in Kenya, (ii) document the challenges towards the adoption of agricultural biotechnology in addressing food insecurity and poverty alleviation in Kenya, and (iii) identify the possible strategic pathways towards the adoption of agricultural biotechnology in addressing food insecurity and poverty alleviation in Kenya. Study findings are expected to contribute to the improvement of the agricultural biotechnology field with the aim of achieving food security and alleviating poverty, so as to enable the country to achieve the first two SDGs. The next section of the paper presents the methodology employed in the study.

Methodology

Research Design

The study adopted a Desktop Research Design guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This method ensured a structured, transparent, and comprehensive analysis of current scholarly discourse.

Search Terms

Search terms were coined based on key terms from the research objectives. The Boolean operators ‘AND’ and ‘OR’ were used to combine these key terms to refine the search and ensure the inclusion of diverse yet relevant articles. In addition to this, advanced search techniques, specifically wildcards (truncations) and Boolean nesting (parentheses), were used to ensure novelty. The search terms included: (Agricultural biotechnology) OR (Genetically Modified*) AND (Food Security), (Agricultural biotechnology) OR (Genetically Modified*) AND (Poverty alleviation)

Electronic Databases Searched

Wiley Online Library, Scopus, ScienceDirect, Taylor & Francis, and Google Scholar were the databases from which literature was sought. The main hitch faced during the use of these databases was the difficulty in controlling the searches despite using advanced search techniques. Restricting the search phrases to the article titles remained a challenge. The use of Zotero referencing software, however, made it feasible to only select and import articles having the desired phrases within the title and abstract.

Criteria for Inclusion

For journal articles, specific criteria had to be met. They must have been written in the English language, be peer-reviewed, have empirical data, be relevant to the objectives under study, and have not been published more than ten years ago (since 2015). In addition to this, Master's Theses, PhD Dissertations, conference papers, policy papers, as well as reports from relevant authoritative bodies such as FAO, GoK, UN, and KIPPRA were used to justify the argument of this paper.

Criteria for Exclusion

Any article published before the year 2015 was automatically excluded, as the content was considered obsolete. This was made possible by using the custom range feature on the e-databases. Articles in other formats besides PDF and those that could not be imported to Zotero were also excluded. The exclusion criteria were heavily hinged on the four-step pathway postulated by Shamseer et al. (2015). Figure 1 presents the inclusion-exclusion pathway.

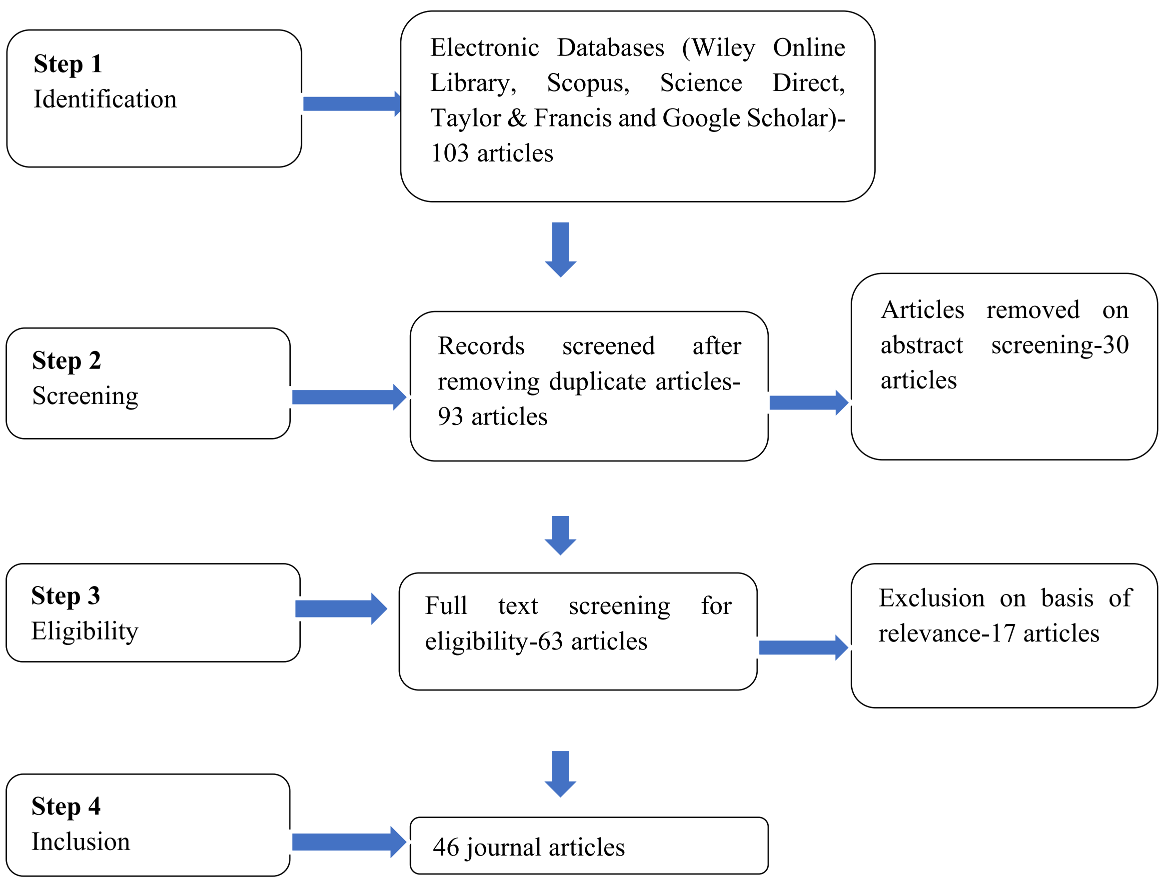

Figure 1: Exclusion and Inclusion Pathway

Results and Discussion

Prospects of Agricultural Biotechnology in Addressing the Food Insecurity and Poverty Situation in Kenya

In the year 2000, a total of 189 countries pledged to emancipate their citizens from absolute poverty and hunger. This pledge turned into the eight Millennium Development Goals (MDGs), which would reduce levels of hunger, malnutrition, and poverty by half by the year 2015 (FAO 2023). These MDGs were later amplified into the 17 UNSDGs to accommodate more contemporary issues that are all to be addressed by the year 2030. Eradication of extreme poverty and hunger remains the top agenda. Kenya, being a member of the United Nations and therefore committed to achieving the SDGs, has to strive to end poverty and hunger among its citizens by 2030. The application of biotechnology in agriculture has the potential to solve this quagmire of poverty and food insecurity.

Kenya, like the majority of African nations, has approached the issue concerning the adoption of agricultural biotechnology with much skepticism. The country took a historic step and partially lifted the ban on GMOs in December 2019, and finally fully lifted the decade-long ban on 3rd October 2022 to address food insecurity and reshape the agricultural sector following the long drought that hit the country. (University of Nairobi, 2023; Alliance for Science, 2024). The lifting of the ban came after consultative and extensive research involving the ministries of Agriculture, Health, and Environment on the impacts associated with the adoption of agricultural biotechnology. Upon lifting the ban, various agricultural organizations, such as the Kenya Agricultural and Livestock Research Organization (KALRO), spearheaded research with an aim of developing better crop varieties and livestock breeds for commercialization. Table 1 presents a summary of the research.

Table 1: Agricultural Biotechnology Field Trials in Kenya

Product	Trait of Interest	Developers	Expected Date of Commercialization
Corn	Insect resistance (MON 810) and drought, disease tolerance (MON 87460)	KALRO, African Agricultural Technology Foundation (AATF)	2024
Cassava	Resistance to Cassava Brown Streak Disease (CBSD)	KALRO, International Institute of Tropical Agriculture (IITA), National Agricultural Research Organization (NARO), University of Nairobi (UoN), International Service for the Acquisition of Agri-biotech Applications (ISAA)	2024/2025
Sorghum	Enhanced vitamin A levels, bioavailable zinc, and iron	KALRO, Agriscience, Corteva, Africa Harvest Biotechnology Foundation International (AHBFI)	2024
Potato	Resistance to late blight (3 R-gene LBR), higher yields	KALRO, International Potato Centre (CIP), Michigan State University (MSU)	2024/2025

Cattle	Resistance to trypanosomes, improved quality, and quantity of yields	KALRO, International Livestock Research Institute (ILRI)	2025

Source (United States Department of Agriculture: Foreign Agricultural Service, 2023)

As is evident in Table 1, agricultural biotechnology aims at enhancing food security through three main ways: higher quantitative yields, improved nutritive quality, and better adaptation to existing environmental stress such as drought, pests, parasites, and diseases. These benefits can be classified into the three main components of sustainable agriculture, which include health, economic, and environmental. (USAID, 2024; Raman, 2017; Azadi et al., 2016). Owing to the skepticism and stringent regulations surrounding the cultivation and consumption of genetically modified products, to date, insect-resistant Bacillus thuringiensis (Bt) cotton remains the only product that has been fully commercialized in Kenya by virtue of being a non-food crop.

The crop was commercially released on 19th December 2019 by the Kenyan government through the Ministry of Agriculture and has proven to be a game changer towards the revitalization of the ailing textile industry. In comparison to the indigenous cotton varieties, Bt. Cotton has superior qualities that are deemed beneficial to the smallholder Kenyan farmers. Higher yields, reduced pesticide use, lower production costs, and improved fiber quality are some of the benefits associated with this cotton variety. (Swilla et al., 2016). Cultivation of this genetically modified cotton variety is slowly reviving the cotton value chain. As of 2024, the country produced approximately 25,000 bales of cotton, which was an improvement from the 18,000 bales produced in the year 2023 (Karimbhai et al., 2022).

Bt. Cotton is extensively cultivated in Homa Bay, Kisumu, and Busia regions, but plans are underway to introduce it to other cotton-growing areas such as Lamu, Machakos, Siaya, Embu, and Makueni, to enable the country to meet the local demand of 200,000 bales per year and halt importation from Uganda and Tanzania. (Atieno, 2024). The successful introduction of this genetically superior cotton variety is envisaged to revive various cotton ginneries in the country, including Kikomi and Rivatex, which shut down due to insolvency, culminating from an acute shortage of cotton. This could create more employment opportunities, thus alleviating poverty. Case studies from China, India, Brazil, and the USA, which are paragons in cotton production, producing 80.4 million bales annually (75 percent of the global production), have shown that biotechnology is very crucial in boosting yields. (Shukla et al., 2018; Levidow et al., 2020; Liang, 2016).

Agricultural biotechnology has also proven to be a critical component in maize production. Maize (*Zea mays*) is an important food crop cultivated in most parts of the world, especially in low- and middle-income countries (LMICs). Globally, it is the third most grown cereal crop that serves as the primary source of food to more than one billion people (Koskei et al., 2020; FAO, 2023). In Kenya, maize and its products are the staple food for the majority of the population, with an annual per capita consumption of approximately 77 kilograms, and for this reason, it is the most widely cultivated crop with approximately 2.55 million hectares under production (FAO, 2018; Aluoch et al., 2022). Besides human consumption, the crop is sometimes processed into silage, which is a form of highly nutritious livestock feed.

Despite the economic value of the crop and its potential to steer the country towards achieving the second SDG, meager harvests of approximately 1.77 tonnes per hectare, which is far below the recommended 6 tonnes per hectare, as a result of environmental stress such as drought, pests, diseases, and post-harvest losses, have been reported. (FAO, 2016; Mwangi & Eli, 2017; Njeru et al., 2022). Koskei et al. (2020) established that the local hybrid maize varieties produced and distributed by various seed companies are more prone to this environmental stress, resulting in huge economic losses among smallholder farmers. Maize Lethal Necrosis Disease (MLND), for instance, contributes to an estimated annual loss of maize valued at 67 million USD. (Eunice et al., 2021; Njeru et al., 2022). Constantine et al. (2020) highlighted that field pests such as fall armyworms, aphids, and stalk-borers also contribute to significant losses in maize farming, which can be curtailed by developing resistant varieties. This is much more feasible with the adoption of agricultural biotechnology.

Case studies revealed that those nations that have fully embraced agricultural biotechnology in maize production tend to have better yields and economic gains as genetic modification improves yields by approximately 25 percent (Megan, 2019). In the USA, for example, it is estimated that approximately 94% of the corn planted is genetically modified and occupies over 86 million acres. The crop is engineered to be resistant to herbicides, pests, and diseases, thus reducing the need for agrochemicals and also increasing yields (Thomson, 2015(Megan, 2019). The minimal application of agrochemicals reduces production costs, thus guaranteeing more economic gains to the farmers, and improving their living standards (Sharma et al., 2024). Through the adoption of agricultural biotechnology, data from the United States Department of Agriculture Foreign Agricultural Service (2018) revealed that the country has been ranked as the leading producer of the crop, accounting for over 35 percent of the global production, and it is mainly utilized as livestock feed, processed food, and in the production of ethanol.

As indicated in Table 1, Kenya is on the verge of commercializing genetically modified maize. KALRO and AATF are still conducting trials on developing maize varieties that are resistant to pests, diseases, and drought. Research field trials for these maize varieties were completed in March, 2021 at six National Performance Trial (NPT) sites: Alupe, Kibos, Kakamega, Embu, Thika, and Mwea (USDA, 2023). Just as is the case with the USA, commercialization of these genetically modified maize varieties is envisaged to present an auspicious opportunity to the Kenyan farmers.

Over 80 percent of the Kenyan farmers practice small-scale farming. The acute shortage of viable farmland can be attributed to various factors such as rapid increase in human population, urbanization, and land grabbing among the elites, which dates back to the colonial era (Khamisi, 2018). With a 25 % increase in yields, a farmer with one hectare of land who opts to grow genetically modified maize is likely to harvest 2.5metric tons in comparison to the two metric tons obtained by the counterpart who decides to grow the non-genetically modified version of the same crop (Megan, 2019). With such high yields in staple food crops such as maize, Kenya can strive to achieve food security. Furthermore, the high resistance to pests, diseases, and adverse environmental conditions will likely reduce the expenditure on agro-chemicals, which in turn will minimize the production costs. With higher income against lower expenditure, Kenyan farmers are most likely to realize more profit retention, thus improving their living standards.

The application of biotechnology in farming has also been linked to several health benefits. The resistance to pests, parasites, diseases, and other environmental stress reduces the rate of agrochemical use, which ensures that the produce meets the internationally accepted Minimum Residue Levels (MRLs) (Meemken & Qaim, 2018; Areri, 2023). In the USA, for instance, adoption of Bt. Maize has reduced pesticide and herbicide use by over 60% (Meemken & Qaim, 2018). Commercialization of Bt. Maize in Kenya will therefore not only bring financial gains but health benefits as well. Improved flavor and higher nutritional content of food produced are other health benefits attributed to agricultural biotechnology.

In the wake of the 21st century, globalization has brought about a change in the dietary patterns and food preferences among consumers, putting much pressure on the agriculture sector to deliver the required quality. (Chen et al., 2021). Ogemah (2017) observed that food demand is not only increasing in terms of quantity but also in terms of diversity and sophistication. Traditional foods like sorghum need genetic modification to enhance palatability and nutritional content. As indicated in Table 1, field trials are ongoing to come up with highly nutritious sorghum varieties. In beef production, there is currently a higher demand for lean meat, thus necessitating the breeding of animals with a higher proportion of muscle to fat. In dairy production, milk with higher butterfat and protein content and low water content is highly demanded among consumers due to its high nutritional content and ease of processing. (Okello, 2020; Howard et al., 2021; Radeny et al., 2022). Research by KALRO and ILRI is aiming at boosting livestock farming through genetic engineering to enhance the quality and quantity of yields. This will prove to be a crucial milestone in the economic development of the country, especially the ASAL regions, which, according to the GoK (2024) face high levels of poverty and food insecurity, but are suitable for livestock production.

The adoption of biotechnology in agriculture has also been linked to environmental benefits. The agriculture sector has, for a long time, been touted as one of the key contributors to aggravating environmental degradation, especially through the excessive application of agro-chemicals (Recha et al., 2025; Alvarado & Toledo, 2017; Gomiero, 2016). Rather than being part of the problem, agricultural biotechnology offers a solution. Azadi et al (2016) argue that since genetically modified crops have a faster growth rate, they tend to outgrow weeds, which in turn reduces or completely eliminates the use of herbicides. Minimum tillage is also achieved during this process, which in turn maintains soil structure. The resistance to pests and diseases, on the other hand, reduces the rate of pesticide application. This, in turn, encourages organic farming, which minimizes pollution resulting from excessive use of agrochemicals. (Meemken & Qaim, 2018; Areri, 2023).

Countries like Brazil, India, and the USA have successfully demonstrated how innovation can co-exist with sustainability. In these countries, integrated farming systems combine modern agricultural biotechnology with traditional practices, boosting productivity while preserving biodiversity (Shukla et al., 2018; Kumar et al., 2020)—the introduction of Bt. Cotton in Kenya has reduced pesticide use by almost 50 percent in Homabay, Kisumu, and Busia counties, which has in turn significantly reduced the rate of water pollution (Atieno, 2024). Adoption of biotechnology in other widely grown crops, such as maize, is likely to significantly reduce the rate of environmental degradation. In livestock production, resistance to trypanosomes will likely lessen efforts aimed at eradicating tsetse flies, such as the use of insecticides and bush clearing, which have a negative impact on the environment.

Challenges towards the Adoption of Agricultural Biotechnology in Kenya

Despite the vast opportunities associated with agricultural biotechnology, its adoption, especially in the developing world, is always marred by controversies and hurdles as a result of such factors as lack of sufficient information, misconceptions, regulations, ignorance, and philosophical concerns. (Muzhinji & Ntali, 2021). Although proponents argue that through the application of agricultural biotechnology techniques such as genetic engineering, food security and agricultural efficiency can be achieved within the shortest possible time, a closer examination of evidence from countries that have fully embraced the same raises concerns about potential risks and long-term effects. (Levidow et al., 2020; Muzhinji & Ntali, 2021). Furthermore, Akinbo et al.(2021) established that organizations rallying for the incorporation of agricultural biotechnology in Africa, Kenya inclusive, are mostly foreign-based, and this raises ethical concerns on whether the real motive is poverty and hunger alleviation among the African countries or profit gains for the foreigners. Research on the merits and demerits of agricultural biotechnology in Africa is also spearheaded by these very same foreign-based corporations, which further raises speculations and puts into question the level of transparency and bias of these findings.

Independent, unbiased, and long-term studies conducted in some countries on the potential impact of the incorporation of agricultural biotechnology, specifically GMOs, on health, socio-economic development, and the environment, warrant careful and sagacious consideration before decision-making. Separate studies by Quiroz (2025) and Tyczewska et al. (2023) linked regular consumption of glyphosate, a common herbicide applied to control weeds in GMCs, to the development of antibiotic-resistant bacteria in the digestive system. This raises serious public health concerns as antibiotic resistance is already a growing global menace. Additionally, the consumption of GMOs has also been linked to organ damage. Lowry et al. (2019) Raised concerns over potential kidney and liver damage in rats fed on a GM maize diet. Omollo (2025), however, affirmed that these findings were preliminary and required further investigation. In the USA, where GMCs have been prevalent for decades, there has been a rise in food-related health issues such as allergies, gastrointestinal disorders, and autoimmune diseases. Although the causation has not been definitively established, the correlation cannot simply be ignored (Megan, 2019). The majority of the Kenyan populace is already vulnerable to and grappling with a range of health-related challenges, such as cancer, obesity, malnutrition, HIV/AIDS, Malaria, tuberculosis, and many others. Introducing agricultural biotechnology through GMO production without prior evaluation to assess the potential health impacts could exacerbate these problems, burdening the already fragile healthcare system.

The environmental impact of agricultural biotechnology is another critical concern. Studies have shown that the cultivation of GMCs, for instance, can lead to biodiversity loss, soil degradation, and the emergence of super-weeds resistant to herbicides (Tsatsakis et al., 2017; Levidow et al., 2020). The USA and Europe, which are often championed as paragons of agricultural biotechnology, have had a problematic track record with respect to biodiversity loss and environmental degradation. Scott et al. (2016) and Fagorzi et al. (2023) pointed out that in the USA, over-reliance on herbicide-tolerant GMCs has resulted in herbicide-resistant weeds, necessitating the use of stronger and potentially more harmful chemicals. The aftermath of this is the creation of a vicious cycle of increasing herbicide resistance, posing a significant threat to the ecological balance of the natural ecosystem. Kenya, with its rich biodiversity, which makes it one of the best tourist destinations in Africa, cannot risk any further ecological threats amidst the reduction in forested land and the increased rate of pollution of the natural water bodies as a result of increased agricultural activities. Any further ecological imbalance may culminate in dwindling revenue from the tourism sector, which contributes significantly to the economy of the country (Berman, 2021). The introduction of GMCs without prior environmental assessment could therefore disrupt natural ecosystems, affecting the natural coexistence between flora and fauna. This could have cascading effects on food chains and food webs, leading to the extinction of some forms of life that may be crucial to mankind.

Adoption of Genetically Modified Crops (GMCs) poses profound implications for Kenya's small-scale farmers, who form the backbone of the nation's agricultural sector. Although proponents opine that agricultural biotechnology offers an avenue for higher yields, which is more likely to benefit small-scale farmers as a result of economies of scale, critics, on the other hand, point out that the introduction of agricultural biotechnology is more likely to be intertwined with imminent socio-economic challenges (Nasike, 2022). Some of the challenges highlighted in various prior studies include; higher price of GM seeds, difficulties in research and development, shortages of the delivery system, lack of information about application of the technology, leading to monopolies by patents on genes, limited global market due to growing skepticism toward GM foods and disrupting traditional cultivation systems (Thomsom, 2015; Azadi et al., 2016; Gebretsadik & Kiflu, 2018; Ali et al., 2019; Kibuacha, 2022). Shukla et al. (2018) attenuate that in India, for instance, the introduction of GM cotton initially increased yields, but later on trapped the local Indian farmers in cycles of debt due to the rising seed and input costs. Similarly, in Burkina Faso, farmers abandoned cultivation of Bt cotton introduced by the American company, Monsanto (Bayer), and reverted to cultivating indigenous varieties, citing poor quality, low yields, and high seed prices. (Nasike, 2022).

Nasike (2022) predicts that, just as it was the situation in India and Burkina Faso, Kenyan farmers are likely to become dependent on costly patented seeds and other agricultural inputs associated with agricultural biotechnology from the multinational corporations, undermining their autonomy and resilience. Organizations like the AATF and the Gates Foundation have played a role in promoting agricultural biotechnology by advocating for the cultivation of GMCs in Kenya. While they champion food security, their partnership and close ties to biotechnology giants such as Monsanto raise ethical concerns about their real motives. In November 2021, cotton farmers in Busia were asking the Kenyan government to subsidize the price of Bt cotton seed, which was retailing at 2,200 Kenyan shillings (16.92 USD) per kilogram. In March 2022, there was an outcry from cotton farmers in Kenya because of the unavailability of Bt cotton seed, which the chief executive officer of the National Biosafety Authority attributed to the multiplication challenges experienced by the sole company given the task; companies fronting the GM crops, such as Mahyco, in which Monsanto has a 26 per cent stake, control the production and multiplication of these crops (Nasike, 2022; Omollo, 2025; Kagonye, 2025). With the full lifting of the ban on GMOs, the introduction of patented seeds in staple foods like maize, wheat, and rice may not go well with the Kenyan farmers, as they may end up being entangled in a vicious cycle of poverty as a result of high seed costs.

The many controversies and skepticism surrounding agricultural biotechnology, especially GMOs, have led to their complete ban in several countries. Globally, countries like Russia take a cautious approach towards the incorporation of agricultural biotechnology. With stringent regulations, Russia prohibits the cultivation of GMCs and rather emphasizes agricultural practices that place greater emphasis on sustainable agricultural practices over corporate-driven GMCs (Vorotyntseva et al., 2019). In the East African region, Kenya is the first country to lift the ban on GMOs, although trials are ongoing in Ethiopia and Uganda (Gebretsadik & Kiflu, 2018; Bachewe et al., 2018). The move to lift the ban on GMOs in Kenya puts the country at loggerheads, especially with neighbouring Uganda and Tanzania, which happen to be Kenya's trade partners (Nasike, 2022; Kagonye, 2025). This is likely to hinder transnational trade. With the loss of market comes the loss of interest in farming and the abandonment of land, which in turn could lead to rural-urban migration by populations in search of alternative livelihoods, leaving the door wide open for multinational corporations to buy abandoned land to grow commercial crops for export. This is likely to aggravate the already fragile food insecurity and poverty situations.

Lack of information about the application of the technology is another imminent problem in Kenya. Agricultural biotechnology is hinged on knowledge and technical skills from other areas of study, such as Genetics, Physiology, and Biochemistry, and therefore requires a well-informed and skillful workforce. To the contrary, the majority of Kenyan farmers are semi-literate and mainly comprise the elderly, as Sebotsa et al.(2021) observed that the youth who are more receptive to agricultural biotechnology are less interested in farming as a career. Availing of information about agricultural biotechnology to these farmers and the general public through reputable means, such as extension workers and health practitioners, has not been effective, which in turn limits the level of awareness. In a recent study conducted by Geopoll, 60% of the respondents believe there is not enough information about GMO foods available to help the masses form a proper opinion. (Kibuacha, 2022). The study further probed to ascertain the sources of information about GMOs. Electronic sources of information, such as Television, social media platforms, websites, and radio, may not be accessible to the poor and vulnerable populace, especially in rural areas, which form the majority of the farmers. Newspapers, on the other hand, may not be very useful sources of information to the illiterate populace. Furthermore, such sources may lack credibility and expert opinion. The study further sought to establish the most preferred sources of information regarding GMOs.

Based on the findings, agricultural professionals were the most trusted sources of information regarding agricultural biotechnology. In developed countries such as the USA and China, extension services are effective in changing perceptions towards the incorporation of agricultural biotechnology.(Norton & Alwang, 2020). In Kenya, as is the case in most other developing countries, extension services are still poor, which has been attributed to such factors as a shortage of extension workers leading to a high farmer: extension worker ratio and inadequately trained extension agents (Ogemah, 2017;Takahashi et al., 2020; Omondi et al., 2023). Kenyans are therefore less likely to receive information about the safety of the consumption of GMOs from extension workers. With a lack of information from reputable sources, Kenyans are not likely to embrace agricultural biotechnology. This might jeopardize the efforts to alleviate poverty and hunger.

Strategic Pathways towards the Integration of Agricultural Biotechnology in Kenya

Agricultural biotechnology techniques, specifically genetic engineering, come with both opportunities and challenges. These challenges call for urgent solutions if agricultural biotechnology is indeed meant to address the rising food insecurity and poverty alleviation. Various scholars have identified various possible solutions. According to Omollo (2025), independent research commissioned by the Kenyan government to assess the potential environmental, health, and socio-economic impacts of agricultural biotechnology can help dispel any fear emanating from misconceptions relating to GMOs.

In order to assess the possible environmental, health, and socio-economic impacts of genetically modified organisms, the National Biosafety Authority (NBA) was established by the Biosafety Act No.2 of 2009. The NBA is the main regulatory agency within the Ministry of Agriculture, Livestock, and Fisheries, tasked with the responsibility of overseeing the formulation and implementation of policies and regulations governing the application of agricultural biotechnology in Kenya (United States Department of Agriculture: Foreign Agricultural Service, 2023). The NBA has formulated four crucial regulations to help in achieving its mandate. These regulations include: Contained Use Regulation, Environmental Release Regulation, Export, Import, and Transit Regulation, and Labeling Regulation. The agency has also established a logical process for the approval of genetically modified crops before commercialization.

To achieve its mandate, the NBA relies on expert opinions and research reports from specialists in various fields. It is in line with this that the agency works closely with eight other regulatory agencies from various ministries. These other agencies working closely with NBA include: Kenya Plant Health Inspectorate Service (KEPHIS), Department of Public Health (DPH), Kenya Bureau of Standards (KEBS), National Environment Authority (NEMA), Pest Control Products Board (PCPB), Kenya Wildlife Service (KWS), Department of Veterinary Services (DVS), and Kenya Industrial Property Institute (KIPI). The DPH and KEBS are responsible for safeguarding consumers' health through food safety and quality control. NEMA, PCPB, and KWS work collaboratively to undertake and coordinate research on the possible impacts of agricultural biotechnology on the environment. Kenya can try to emulate countries like Brazil and India, which have successfully demonstrated that agricultural biotechnology can co-exist with sustainability (Shukla et al., 2018; Kumar et al., 2020). KIPI, which falls under the Ministry of Trade, Investment and Industry, administers intellectual property rights and is therefore crucial in safeguarding small-scale farmers from exploitation by biotech firms and ensuring access to affordable and locally adapted seeds and other planting materials. This will shield farmers from draconian intellectual property laws related to patents held by GMO multinationals. The Kenyan government should therefore empower the NBA to ensure it achieves its mandate.

Public participation through engaging all stakeholders, comprising farmers, consumers, researchers, medical practitioners, and extension officers, in transparent dialogue about agricultural biotechnology. Public education is vital to empower citizens with informed choices (Okello, 2025; Kagonye, 2025). Institutions of higher learning, especially universities, have stepped forward in enlightening the masses. The University of Nairobi (UoN) has made laudable efforts in enlightening the masses about agricultural biotechnology. In 2023, following the lifting of the ban on GMOs, the institution organized a public lecture whose theme was '*GMOs are the silver bullet to the hunger situation in Keny*a' (University of Nairobi, 2023). Food and farming system experts were invited to give their expert opinions. If all other institutions of higher learning follow suit, then public perception about agricultural biotechnology is likely to change.

References

Akinbo, O., Obukosia, S., Ouedraogo, J., Sinebo, W., Savadogo, M., Timpo, S., Mbabazi, R., Maredia, K., Makinde, D., & Ambali, A. (2021). Commercial release of genetically modified crops in Africa: Interface between biosafety regulatory systems and varietal release systems. *Frontiers in Plant Science, 12*, 605937. https://www.frontiersin.org/articles/10.3389/fpls.2021.605937/full

Ali, S., Ghufran, M., Nawaz, M. A., & Hussain, S. N. (2019). The psychological perspective on the adoption of approved genetically modified crops in the presence of acceptability constraint: The contingent role of passion. *GM Crops & Food, 10*(4), 220–237. https://doi.org/10.1080/21645698.2019.1680241

Alliance for Science. (2024). *Kenya: Farmers bear the brunt of the delayed adoption of GM crops*. Alliance for Science. https://allianceforscience.org/blog/2024/12/kenya-farmers-bear-the-brunt-of-delayed-adoption-of-gm-crops/

Aluoch, S. O., Li, Z., Li, X., Hu, C., Mburu, D. M., Yang, J., Xu, Q., Yang, Y., & Su, H. (2022). Effect of mineral N fertilizer and organic input on maize yield and soil water content for assessing optimal N and irrigation rates in Central Kenya. *Field Crops Research, 277*, 108420. https://doi.org/10.1016/j.fcr.2021.108420

Alvarado, R., & Toledo, E. (2017). Environmental degradation and economic growth: Evidence for a developing country. *Environment, Development and Sustainability, 19*(4), 1205–1218. https://doi.org/10.1080/01436597.2022.2132927

Areri, V. (2023). *Smallholder farmers' perceptions on adoption of organic farming practices in Kisii Central Sub-County, Kisii County, Kenya* [PhD thesis, Egerton University]. http://ir-library.egerton.ac.ke/handle/123456789/3096

Atieno, O. R. A. (2024). *Influence of socio-economic factors on sustainable production of cotton in Kisumu County, Kenya* [PhD thesis, Kisii University]. http://repository.kisiiuniversity.ac.ke:8080/xmlui/handle/123456789/5711

Bachewe, F. N., Berhane, G., Minten, B., & Taffesse, A. S. (2018). Agricultural transformation in Africa? Assessing the evidence in Ethiopia. *World Development, 105*, 286–298.

Berman, N. (2021). Environmental education catalyzed by tourism: Ecoliteracy initiatives on the coast of Kenya. *Sustainability, 13*(15), 8501. https://doi.org/10.3390/su13158501

Chen, Y., Wang, J., Zhang, F., Liu, Y., Cheng, S., Zhu, J., Si, W., Fan,S., Gu, S., Hu, B., Li, X., & Yu, X. (2021). New patterns of globalization and food security. *Journal of Natural Resources, 36*(6), 1362. https://doi.org/10.31497/zrzyxb.20210602

Constantine, K. L., Murphy, S. T., & Pratt, C. F. (2020). The interaction between pests, mixed-maize crop production, and food security: A case study of smallholder farmers in Mwea West, Kenya. *Cogent Food & Agriculture, 6*(1), 1857099. https://doi.org/10.1080/23311932.2020.1857099

Eibl, R., Senn, Y., Gubser, G., Jossen, V., Van Den Bos, C., & Eibl, D. (2021). Cellular agriculture: Opportunities and challenges. *Annual Review of Food Science and Technology, 12*(1), 51–73. https://doi.org/10.1146/annurev-food-063020-123940

Eunice, J., Miano, D., W.M, M., Mutitu, E., & Macharia, I. (2021). Status of maize lethal necrosis disease in the seed production system in Kenya. *Cogent Food & Agriculture, 7*(1), 1918406. https://doi.org/10.1080/23311932.2021.1918406

Fagorzi, C., Passeri, I., Cangioli, L., Vaccaro, F., & Mengoni, A. (2023). When biodiversity preservation meets biotechnology: The challenge of developing synthetic microbiota for resilient, sustainable crop production. *Journal of Sustainable Agriculture and Environment, 2*(1), 5–15. https://doi.org/10.1002/sae2.12038

Food and Agriculture Organization [FAO]. (2016). *Comprehensive food security and vulnerability analysis and nutrition assessment in Kenya high-density urban areas*. Taylor & Francis. Retrieved on 16-04-2022 from www.disaterriskreduction.net

Food and Agriculture Organization [FAO]. (2018). *Report on the state of food security and nutrition*. Accessed on 4-10-2022 from www.fao.org

Food and Agriculture Organization of the United Nations. (2023). *Hunger and food insecurity*. Google Docs. https://www.fao.org/hunger/en

Giwu, O., Mdoda, L., & Ntlanga, S. S. (2024). Assessing the socio-economic impact of youth engagement in agricultural enterprise for employment creation and poverty alleviation. *Cogent Social Sciences, 10*(1), 2368097. https://doi.org/10.1080/23311886.2024.2368097

Gomiero, T. (2016). Soil degradation, land scarcity, and food security: Reviewing a complex challenge. *Sustainability, 8*(3), 281. https://doi.org/10.3390/su8030281

Government of Kenya. (2024). *Integrated Food Security Phase Classification: Evidence and standards for better food security and nutrition decisions* (p. 24). Integrated Food Security Phase Classification. https://www.ipcinfo.org/fileadmin/user_upload/ipcinfo/docs/IPC_Kenya_Acute_Food_Insecurity_Acute_Malnutrition_Feb_June2024_Report.pdf

Howard, A. P., Slaughter, L. S., Carey, K. M., & Lillard, J. W., Jr. (2021). Bridges to biotechnology and bioentrepreneurship: Improving diversity in the biotechnology sector. *Nature Biotechnology, 39*(11), 1468–1474.

Kagonye, F. (2025). *GMO maize will hit your plate after the end of public participation*. *The Standard Newspaper, 8*(2), 1–30.

Karimbhai, M., Gebre, K. E., Joe, G., & Tinga, O. J. (2022). The value chain of the cotton industry in Kenya, with a focus on product stewardship for the timely provision of certified quality hybrid Bt cotton seeds to farmers. *African Journal of Biotechnology, 21*(8), 361–379. https://doi.org/10.5897/AJB2022.17452

Kenya Institute for Public Policy Research and Analysis. (2020). *Kenya economic report 2020: Creating an enabling environment for inclusive growth in Kenya* (p. 22). https://kippra.or.ke/wp-content/uploads/2021/02/Kenya-Economic-Report-2020-Popular-Version.pdf

Khamisi, J. (2018). *Kenya: Looters and grabbers: 54 years of corruption and plunder by the elite, 1963–2017*. Jodey Book Publishers.

Kibuacha, F. (2022, November 14). *GMO foods in Kenya: Awareness and perceptions – GeoPoll report*. GeoPoll. https://www.geopoll.com/blog/gmo-foods-kenya-report/

Koskei, P., Bii, C. C., Musotsi, P., & Muturi, S. K. (2020). Post-harvest storage practices of maize in Rift Valley and Lower Eastern regions of Kenya: A cross-sectional study. *International Journal of Microbiology, 5*(3), 1–13. https://doi.org/10.1155/2020/6109214

Kumar, K., Gambhir, G., Dass, A., Tripathi, A. K., Singh, A., Jha, A. K., Yadava, P., Choudhary, M., & Rakshit, S. (2020). Genetically modified crops: Current status and prospects. *Planta, 251*(4), 91. https://doi.org/10.1007/s00425-020-03372-8

Levidow, L., Carr, S., & Wield, D. (2020). Genetically modified crops in the European Union: Regulatory conflicts as precautionary opportunities. *Journal of Risk Research, 3*(3), 189–208. https://doi.org/10.1080/136698700500043062

Liang, C. (2016). Genetically modified crops with drought tolerance: Achievements, challenges, and perspectives. In M. A. Hossain, S. H. Wani, S. Bhattacharjee, D. J. Burritt, & L.-S. P. Tran (Eds.), *Drought stress tolerance in plants* (Vol. 2, 1st ed., pp. 531–547). Springer International Publishing. https://doi.org/10.1007/978-3-319-32423-4_19

Lowry, G. V., Avellan, A., & Gilbertson, L. M. (2019). Opportunities and challenges for nanotechnology in the agri-tech revolution. *Nature Nanotechnology, 14*(6), 517–522.

Meemken, E.-M., & Qaim, M. (2018). Organic agriculture, food security, and the environment. *Annual Review of Resource Economics, 10*(3), 39–63.

Muzhinji, & Ntali, V. (2021). Genetically modified organisms and food security in Southern Africa: Conundrum and discourse. *GM Crops & Food, 12*(1), 25–35. https://doi.org/10.1080/21645698.2020.1794489

Mwangi, P. N., & Eli, A. (2017). Assessing risks and benefits: Bt maize in Kenya. *2*(1), 1–31.

Nasike, C. (2022). GMOs: A neo-colonial technology undermining food and seed sovereignty in Kenya. *Greenpeace Africa, 30*(2), 234–243. https://www.greenpeace.org/africa/en/publications/52437/gmos-a-neo-colonial-technology-undermining-food-and-seed-sovereignty-in-kenya/

Njeru, F., Mwaura, S., Kusolwa, P. M., & Misinzo, G. (2022). Maize production systems, farmers' perception, and current status of maize lethal necrosis in selected counties in Kenya. *All Life, 15*(1), 692–705. https://doi.org/10.1080/26895293.2022.2085815

Norton, G. W., & Alwang, J. (2020). Changes in agricultural extension and implications for farmer adoption of new practices. *Applied Economic Perspectives and Policy, 42*(1), 8–20. https://doi.org/10.1002/aepp.13008

Okello, D. (2020). Gender effect of entrepreneurial orientation on dairy farming career resilience in Kenya. *Cogent Food & Agriculture, 6*(1), 1863565. https://doi.org/10.1080/23311932.2020.1863565

Olasoju, S. A., Adekunle, O., Edun, T., & Owoseni, J. (2018). Problems and prospects of agricultural biotechnology in Nigeria's developing economy. *International Journal of Biological, Life and Agricultural Sciences, 12*, 2415–6612.

Omondi, I. A., Maina, S. W., Moyo, M., & Muzhingi, T. (2023). Do farmers' production and consumers' utilization of sweet potatoes match? A case of the role of extension in Homa Bay and Kisumu Counties, Kenya. *African Journal of Food, Agriculture, Nutrition and Development, 23*(2), 22470–22491. https://doi.org/10.18697/ajfand.117.22475

Ouko, K. O., Ogola, J. R. O., Ng'on'ga, C. A., & Wairimu, J. R. (2022). Youth involvement in agripreneurship as a nexus for poverty reduction and rural employment in Kenya. *Cogent Social Sciences, 8*(1), 2078527. https://doi.org/10.1080/23311886.2022.2078527

Quiroz, I. V. (2025). Ethical and social challenges of environmental biotechnology. In *Soil improvement and water conservation biotechnology* (pp. 322–343). Bentham Science Publishers. https://www.benthamdirect.com/content/books/9789815322439.chapter-14

Radeny, M., Rao, E. J., Ogada, M. J., Recha, J. W., & Solomon, D. (2022). Impacts of climate-smart crop varieties and livestock breeds on the food security of smallholder farmers in Kenya. *Food Security, 14*(6), 1511–1535. https://doi.org/10.1007/s12571-022-01307-7

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

Recha, R., Ndambuki, R., Konyango, J., & Waiganjo, M. (2025). An overview of the contribution of secondary school agriculture curriculum and the YFCK activities towards promoting students' participation in sustainable farming practices in Kenya. *International Journal of Education, Technology and Science, 5*(1), 1–25. https://doi.org/10.5281/zenodo.14903803

Ruzzante, S., Labarta, R., & Bilton, A. (2021). Adoption of agricultural technology in the developing world: A meta-analysis of the empirical literature. *World Development, 146*, 105599. https://doi.org/tps://doi.org/10.1016/j.worlddev.2021

Scott, S. E., Inbar, Y., & Rozin, P. (2016). Evidence for absolute moral opposition to genetically modified food in the United States. *Perspectives on Psychological Science, 11*(3), 315–324. https://doi.org/10.1177/1745691615621275

Sebotsa, K. O., Nkurumwa, A., & Kyule, M. (2021). Effect of utilization of social media platforms on youth participation in agriculture in Njoro Sub-County, Kenya. *International Journal of Agricultural Extension, 8*(3), 235–250. https://doi.org/10.33687/ijae.008.03.3400

Serugo, P., Ssentongo, J. S., & Byalebeka, J. (2024). Reflections on social justice in the promotion of biotechnology crops and institutionalisation of food values among smallholder farmers in Central Uganda. *7*(2). https://doi.org/10.37284/eajab.7.2.2380

Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. *BMJ, 349*. https://www.bmj.com/content/349/bmj.G7647.abstract

Sharma, A., Arya, S. K., Singh, J., Kapoor, B., Bhatti, J. S., Suttee, A., & Singh, G. (2024). Prospects of chitinase in sustainable farming and modern biotechnology: An update on recent progress and challenges. *Biotechnology and Genetic Engineering Reviews, 40*(1), 310–340. https://doi.org/10.1080/02648725.2023.2183593

Shavanov, M. V., Adaev, N. L., & Khamkhoeva, F. (2022). Development and prospects of agricultural biotechnologies. *AIP Conference Proceedings, 2390*(1), 030082. https://pubs.aip.org/aip/acp/article-abstract/2390/1/030082/2821143

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

Swilla, J., Waturu, C. N., & Rubindamayugi, S. T. (2016). Impact of transgenic cotton expressing *cry1Ac* and *cry2Ab* genes on soil rhizosphere bacterial and fungal populations in soils of Central Kenya. *African Journal of Biotechnology, 15*(21), 930–939. https://doi.org/10.5897/AJB2013.13125

Takahashi, K., Muraoka, R., & Otsuka, K. (2020). Technology adoption, impact, and extension in developing countries' agriculture: A review of the recent literature. *Agricultural Economics, 51*(1), 31–45. https://doi.org/10.1111/agec.12539

Thomson, J. A. (2015). Prospects for the utilization of genetically modified crops in Africa. *Canadian Journal of Plant Pathology, 37*(2), 152–159. https://doi.org/10.1080/07060661.2015.1035954

Tsatsakis, A. M., Nawaz, M. A., Kouretas, D., Balias, G., Savolainen, K., Tutelyan, V. A., Golokhvast, K. S., Lee, J. D., Yang, S. H., & Chung, G. (2017). Environmental impacts of genetically modified plants: A review. *Environmental Research, 156*, 818–833. https://doi.org/10.1016/j.envres.2017.03.011

Tyczewska, A., Twardowski, T., & Woźniak-Gientka, E. (2023). Agricultural biotechnology for sustainable food security. *Trends in Biotechnology, 41*(3), 331–341.

United Nations Statistical Division. (2024). *World population prospects 2024: Summary of results* (pp. 1–69). Retrieved on 30-11-2024 from https://unstats.un.org/sdgs/files/report/2024/E_2024_54_Statistical_Annex_I_and_II.pdf

United States Agency for International Development. (2024). *What is agricultural biotechnology?* (Vol. 1). USAID. https://pdf.usaid.gov/pdf_docs/pnadl538.pdf

United States Department of Agriculture Foreign Agricultural Service. (2018). *Grain: World markets and trade*. Taylor & Francis. https://apps.fas.usda.gov/psdonline/circulars/grain.pdf

United States Department of Agriculture: Foreign Agricultural Service. (2023). *Agricultural biotechnology annual report* (p. 21) [Biotechnology and Other New Production Technologies].

University of Nairobi. (2023). *GMOS are the silver bullet to the hunger situation in Kenya* (pp. 1–5). Taylor & Francis. https://agriculture.uonbi.ac.ke/latest-news/gmos-are-silver-bullet-hunger-situation-Kenya

Vorotyntseva, T., Dmitrieva, O., Rudakova, E., & Morkovkin, D. (2019). Current issues of food security in Russia. *2nd International Conference on Economy, Management and Entrepreneurship (ICOEME 2019)*, 349–354. https://www.atlantis-press.com/proceedings/icoeme-19/125910819