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EXPLORING THE POTENTIALS OF GENETICALLY MODIFIED ORGANISMS FOR ACHIEVING FOOD SECURITY AND SUSTAINABLE AGRICULTURE: THE DILEMMA OF AFRICAN COUNTRIES

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ABSTRACT

Genetically Modified Organisms (GMOs), which often carry genes from bacteria or virus, have started taking root in Africa. Since the advent of this technology, arguments have been raging between the proponents of GMOs, who believe it has a lot of benefits and can lead to food security in the developing world, and the opponents who are against it. Africa is the second largest and second most populous continent on earth with a projected population of about 2.4 billion by 2050. Certainly, the continent needs to find ways to increase food production in order to solve the problems of food shortage, malnutrition and poverty. Even though agriculture is the most economically important activity providing employment for about two-thirds of the continent's population, it remains at subsistence level with serious challenges, ranging from lack of sophisticated farming tools to insufficient or high cost of fertilizer, inadequate improved seeds, poor soils and poor irrigation facilities, postharvest losses, diseases and pests. The countries have been experimenting with different agricultural programmes and policies, which have not made significant impact on sustainable agricultural development. Can GMOs provide a solution for Africa? This paper explores the potentials of GMOs in achieving food security, the dilemma and implications for Africa.

Keywords: Africa; biotechnology; dilemma; food security; Genetically Modified Organisms
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INTRODUCTON

A genetically modified Organism (GMO) is a plant, animal or micro-organism which DNA has been modified using genetic engineering techniques. Genetic Engineering (GE) is the process by which the genetic make-up of an organism is altered using "recombinant DNA technology". It requires completion of some basic steps: nucleic acid extraction, gene cloning, gene design and packaging, gene transformation, detection of the inserted genes and backcrossing breeding if required (Ojuederie *et al.*, 2011). Through genetic engineering (GE), genes can be transferred between more distantly related organisms than was possible with traditional breeding techniques. The genes can come from any organism, plants, animals, bacteria or viruses and are introduced into another organism thereby completely modifying the organism (Beluch, 2005). Man has for thousands of years used conventional methods through selective breeding and cross breeding to modify plants and animals for desired traits, a process which can take a long time. Within the last few decades, however, that is, with the 1973 discovery of recombinant DNA techniques which allows transfer of genetic materials between unrelated species, GE has allowed scientists to directly modify the DNA of plants, animals and microorganisms, thus marking the beginning of modern biotechnology.

Biotechnology is a collection of scientific techniques that use living organisms or substances from those organisms to improve plants, animals and microorganisms for the benefit of the society. It can be applied in medicine, agriculture, pharmaceutical and food industries, biofuels, etc. Agricultural biotechnology encompasses both traditional biotechnology such as biological control of pests, conventional plant breeding and animal vaccine production as well as modern biotechnology (Umma lele, 2003). With biotechnology, agricultural productivity is increased based on the understanding of DNA. Scientists are able to identify genes that may confer advantages on certain crops and use these characteristics precisely to improve crops and livestock. The modification is carried out in the laboratory in order to enhance desired traits such as increased resistance to herbicides, drought or improved nutritional content (Zerbe, 2008).

The Genetically Modified Organisms have the potential to address hunger and malnutrition challenges as well as protect and preserve the environment by increasing yield and reducing reliance on chemical pesticides and herbicides. Out of the estimated 102 million hectares planted to GM crops in 2006, 57% was planted to soybeans, 25% to maize, 13% to cotton and 5% to canola. The United States has consistently been the world's leading cultivator of GM crops using up to 55% of the total area in 2005. Other countries include Argentina (19%), Brazil (10%), Canada (7%) and China (4%). Fifteen to twenty other countries make up the remaining 5% (Zerbe, 2008).

Since the discovery of GE, arguments have been raging for and against GMOs. In the United States, there has been little resistance to GMOs unlike in Europe where consumers have strongly opposed the incorporation of GMOs and GM products. Monsanto now Bayer has spent US$1.6 million on advertising in Europe to convince consumers on the merits of GM foods (Gibbs, 2000). In the United Kingdom, major food retailers such as ASDA, Marks and Spencer, Iceland, Sainsburry, Waitrose and the Co-op have banned GM products from their own brand food lines which is another big setback (Gibbs, 2000). Public anxiety over the consumption of food products containing GM ingredients is the major reason for the rejection of GMOs in Europe and other countries. Consequently, there has been widespread calls for strong regulatory frameworks to govern the technology in order to protect human health and the environment. The regulations of biotechnology in the United States differ from those of Europe significantly. In the United States, regulation of GMOs is based on a policy termed sound science and the assumption of substantive equivalence while that of Europe is on the basis of precautionary principle.

According to the sound science policy, a corn variety created in the laboratory through genetic engineering is assumed to behave as a hybrid corn variety bred conventionally from two parent lines in the field and are thus regulated under the same system. The product is thus assumed to be safe. The precautionary principle reverses these assumptions and considers the method of production in the regulatory decision- making process. Thus, GE corn, for example, may be governed under a completely different regulatory system than conventional corn. In addition, the burden of proof rests with the producers and not with the regulators. The producers have to prove that their product is safe before it is approved for commercial release (Zerbe, 2008). In as much as technologies for genetically modified organisms offer great potential to ensuring food security, like all new technologies they are full of controversies as a result of which there is moral dilemma associated to its adoption. There is, therefore, need to understand this technology. What are the reasons behind the dilemma and what are the implications of the technology for Africa. Is the continent ready to adopt the technology? Can GMOs co-exist with traditional crops? Can it result in food security in the African continent? This paper is an attempt to examine these issues within the context of food security in Africa.

2.0 FOOD SECURITY

Food security is fundamental to all nations because no nation will like to see its people poor and hungry. It is thus the driving force to national development. At the 1996 World Food Summit, the term "food security" was defined as "when all people, at all times have, physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". That is, food security exists when all members of household at all times have access to enough food for an active and healthy life (FAO, 2004). Another definition also given by FAO is, "food security means that food is available at all times, that all persons have access to it , that it is nutritionally adequate in terms of quality, quantity and variety and that it is available within the given culture (Ahmed *et al*., 2007). There are thus three basic components to food security, namely availability, access and utilisation. One of the main global challenges of this century is how to ensure food security for a global growing population whilst ensuring long-term sustainable development. Sustainable food security is a global problem considering the increasing population which is projected to reach nine (9) billion by 2050. Nearly 1.2 billion people now live in absolute poverty out of which 800 million live under uncertain food security; 160 million pre-school children suffer from malnutrition while a large number of people also suffer from deficiencies of micronutrients such as zinc, iron and vitamin A (Sharma *et al*., 2002). World leaders converged at a millennium summit in 2000, to discuss global problems which include food security and they agreed to work together to find a lasting solution to the problems. Poverty is considered to be the root cause of food insecurity and it was agreed to reduce poverty to half by 2015. This led to the formulation of Millennium Development Goals (MDGs). At the end of 2015, the MDGs were expanded to 17-point Sustainable Development Goals which include eradicating hunger and poverty. The Sustainable Development Goals (SDGs), officially tagged, "Transforming our World: the 2030 Agenda for Sustainable Development", is a set of seventeen aspirational "Global Goals" with 169 targets between them. It is spearheaded by the United Nations and it involves its 193 Member States, as well as global civil society. They made the second aspiration goal to be Zero Hunger - End hunger, achieve food security and improve nutrition and promote sustainable agriculture. This goal is highly important considering that from their analysis:

(ii) Globally, 1 in 9 people are undernourished, the vast majority of these people live in developing countries

(iii) Agriculture is the single largest employer of labour in the world, providing livelihoods for 40 per cent of today's global population. It is the largest source of income and jobs for poor rural households. Women comprise on average 43 per cent of the agricultural labour force in developing countries, and over 50 per cent in parts of Asia and Africa, yet they only own 20% of the land.

(iv) Poor nutrition causes nearly half (45 per cent) of deaths in children under five, i.e. 3.1 million children each year (Mukhtar and Haruna, 2018).

The increase in world's population may not be matched by global food production especially in developing countries. Africa is the second-largest and second most populous continent on earth with an estimated population of 1.38 billion people in 2021(worldometer) and a growth rate of more than 2% every year. In Africa, agriculture is the most important economic activity providing employment for 75% of the continent's population which constitutes 40% of the GDP of African countries (Machuka, 2003). However, agriculture remains at subsistence level on small farms, with low yielding seeds, infertile soil and traditional farming implements, since farming is not mechanised. Africa is blessed with human and natural resources but majority live below the poverty line (Ojuederie *et al*., 2011; Muzhinji and Ntuli, 2020).

The challenge of food security is more serious in developing countries. In Africa the demand for food will increase as the population is projected to reach 2.4 billion in 2050. Food import is expected to increase from 50-70 million tons per annum, which will make it difficult for low-income, food-deficit countries (LIFDCs) to afford (Kelemu *et al*., 2003). Several efforts have been made by African countries in the past to ensure food security but most of these efforts have not yielded the desired result. In Nigeria, for instance, some of the efforts made in the past include the National Accelerated Food Production Programme (NAFPP) in 1960, Operation Feed the Nation, in 1976, Green Revolution Programme launched in 1980. There were also the agency-based intervention programmes which include National Agricultural Land Development Authority (NALDA), River Basin Development Authority (RBDA), Agricultural Development Programme (ADPs) which started in 1972 and the Directorate of Food, Road and Rural Infrastructure (DFRRI) (Daneji, 2011). There was also the Agriculture Transformation Agenda Policy (2011- 2015) which expressed determination to end food imports, particularly rice, and develop cassava and rice value chains while simultaneously adding value to these selected products and create domestic and export markets for farmers (Lokpobiri, 2019). Yet, while these programmes have recorded major successes, many limitations, including lack of continuity, have hindered the much desired goal of achieving self-sufficiency in food (Daneji, 2011). The rate of food import also remained high. The Buhari administration formulated a comprehensive package of policy instruments- Agricultural Promotion Policy 2016-2020 (APP) - to place Nigeria's agricultural sector on the path of sustainable growth and development. The APP identified core challenges and sets out a road map towards addressing the challenges (Lokpobiri, 2019).

In Nigeria about 70% of the population are farmers and even though farming is subsistence on small farms carried out with simple tools, they still produce 80% of the total food. The farmers depend on agriculture as their only source of food, and often their main source of income. Thus agriculture holds the key to food security and to stimulate wider economic growth it's given adequate attention (Lawan, 2011; Lokpobiri, 2019).

Agriculture has changed over the years and is facing multiple challenges due to problems associated with water stress, soil degradation, climate change, pests and diseases. Genetic engineering can result in loss of manpower necessary for agricultural development due to urban migration. People tend to migrate from the rural to urban areas for better opportunities and the migration is highest among the youth aged between 15 -30, who happen to be more productive. This causes a heavy drain on the supply of human labour (Jayne *et al.*, 2002; Mukhtar and Usman, 2018). The reason for the migration could be because farming is not lucrative as the gain from agriculture is meagre due to many reasons including poor pricing of the farm produce, high cost of fertilizer, poor transportation, and lack of good storage facilities. This results in reduction of agricultural production because a large proportion of the people have abandoned farming and taken up other non-agricultural jobs in the cities. The risk posed by rural – urban migration is that the resulting loss of manpower necessary for agricultural development leads to more poverty and food insecurity. Rural - urban migration thus becomes a risk factor to food security. Additional risk factor to food security in Nigeria which is a very serious one is that of insecurity, including insurgency, militancy, banditry, kidnapping and clashes between herdsmen and farmers (Mukhtar and Haruna, 2018). .

These problems are not peculiar to Nigeria but are common issues on the African continent. Post- harvest losses due to spoilage and infestation significantly contribute to food insecurity and in Africa it could reach up to 40%. In monetory terms, post-harvest loss of grain crops is estimated at US$4 billion (Gashu *et al.*, 2019). In the face of the numerous challenges that threaten achievement of food security in the continent, there is the need to focus on alternative farming techniques that can boost food production to feed the population and reduce the level of hunger, malnutrition and poverty.

Genetic Engineering has tremendous potential to address food insecurity and may be regarded as the science of the future. The first genetically engineered (GE) crops to be produced for human consumption were introduced in the mid-1990s. Today, nearly 90% of the corn, soybeans and sugar beet on the market are GMOs. The proponents of GE foods believe that it holds great benefits and can have significant value in Africa's Agriculture both in the short and medium term and that can lead to food security (Cleveland, 2005; Qaim, 2009) with potential for higher yields, longer shelf- life, resistance to diseases and pests and drought tolerance as well as improved taste. However, the development and use of GMOs have remain controversial in Africa and other developing countries because of the arguments that have been raging regarding them. These controversies have increased in the recent years due to the widespread of GMOs and their use in many crops and foods that people consume. Perhaps what has compounded the lack of acceptance in Africa is lack of understanding of the technology and the limited available research. The major issues and fears are categorised into three: health, environmental and socio-economic issues. There is, therefore, the need to proceed with caution due to the uncertainties to health and the environment that trail the technology (Zerbe, 2008).

3.0 GENETICALLY MODIFIED ORGANISMS (GMOs) AND SUSTAINABLE AGRICULTURE

A genetically modified organism (GMO) is an organism whose genome has been altered in the laboratory by scientists using the techniques of genetic engineering. Genetic modification involves identifying the gene of interest for a trait e.g. insect resistant genes, weed resistant genes, genes for longer shelf-life or enhanced nutritional value etc. and inserting the gene of interest into an organism of interest (e.g. insert insect resistance gene into a susceptible plant to make it resistant). This makes the DNA of the organism to contain one or more genes that are not normally found there. For instance, to engineer corn plant that is resistant to insect pests, scientists find a bacterium **[***Bacillus thuringiensis* (Bt)**]** in soil that naturally contains a protein that kills insect pests that feed on corn plants. They extract from the bacteria's DNA the segment, or gene, that makes the toxic protein. Next, a gene gun is used to shoot copies of the segment into the nucleus of corn cells. They grow the cells into plants, harvest the seeds from the plants and grow the seeds into new corn plants. Every cell in the new corn plants and in their offspring is now programmed to make the toxic protein, which kills the insect pests when they try to eat the plants. The genes can come from the same plant species, from wild relatives, from another crop or from bacteria or another organism. Plants that have genes from other organisms are known as transgenic plants (Maghari and Ardekani, 2011; Jaffe, 2012).

Other genetic techniques aside from transferring genes from one organism to another are:

(i) Moving, deleting, modifying or multiplying genes within a living organism
(ii) Modifying existing genes or constructing new ones and incorporating them into a new organism (Sruthi *et al.*, 2013).

Genetically modified foods first appeared in the market in the early 1990s and there is currently a high percentage of foods such as maize, soybean, canola and cotton seed oil that are genetically modified. The purpose of genetic engineering is to increase productivity by introducing qualities such as disease, pests and herbicide resistance, increasing stress tolerance as well as enhancing nutritional value, flavour and shelf life of fresh produce towards global food security. This has simplified and reduced the effort and time farmers take to battle weeds, insects and diseases (Wieczorek, 2003; Jaffe, 2012). Insect tolerance has been induced in some crops through genetic engineering. *Bacillus thuringiensis* (Bt) is a bacterial species that naturally creates proteins that are toxic to insects, but do not affect other animals, humans or plants and most other non- target organisms. The gene that creates this toxin has been transferred into a variety of crops such as corn and cotton. When the insect eats a small amount of the plant, it dies. This eliminates the need to use chemical pesticides. Different Bt genes produce proteins that target different pests (Jaffe, 2012). It has been shown from studies that farmers growing Bt corn reduce the total insect population not only on their farms but the farms of their neighbours thereby extending the benefit to non GE farmers and increasing yield. This technique enhances crop protection. The protein from the soil bacterium has been used for decades as the active ingredient of some natural insecticides (Wieczoreck and Wright, 2012). In a similar way, plants that are not affected by herbicides have been genetically engineered. Some herbicides are known to kill virtually all plants and so cannot be used on crops. GE soybeans, corn, canola, sugar beets, cotton and alfalfa contain a bacterial gene that protects the crops from particular herbicides. With this protection, herbicide can be applied on the crop, and only weeds are killed. This makes it easier for farmers as they can apply the pesticide after crop emergence and not just before (Jaffe, 2012). Some varieties of papaya and squash have been engineered to be resistant to plant viruses and are available for commercial use. These plants contain a gene taken from a virus that protects them against infections caused by the virus (Jaffe, 2012).

GE crops also benefit non- GE farmers because it has been shown from studies that farmers growing Bt corn reduce the total insect population not only on their farms but also the farms of their neighbours who do not grow GE corn resulting in higher yield (Jaffe, 2012). Through genetic engineering, nutritional value, flavour and texture of foods are improved. Healthier fatty acids in soybeans and other oil seeds have been engineered into plants in the laboratory though not yet commercialised (Jaffe, 2012). Also, potatoes with improved amino acid content and more nutritionally available starch, beans with more amino acid, rice with the ability to produce beta – carotene are being developed. Researchers in India have announced the creation of genetically modified potato in which the protein content is increased by a third (Chikaire and Nnadi, 2012). An enzyme known as chymosin is produced by GE bacteria and is now used to manufacture 60% of all cheese in place of calf rennet. It provides high cheese yield efficiency, ensures continuous supply, greater purity and a reduction cost of 50%. The shelf life of fresh produce can also be increased by GE. This makes it easier to transport fresh produce and at the same time decay, damage and loss of nutrients are prevented.

Animals have also been genetically engineered by scientists in the same way they create genetically engineered plants in the laboratory. Though research in this area has been on for 20 years, only few commercially engineered animals are available. These include engineered cow which produces milk that lacks a key protein that triggers allergies, AquaBounty's salmon that grows twice the rate of conventional salmon thereby increasing the sustainable production of the fish. Also, goats engineered with a human gene like a pharmaceutical industry. It produces a bioactive molecule in its milk which is separated from the milk and sold as the drug ATRYN. Agriculture companies are also using biotechnology to improve production of meat and dairy products and to improve processing of other foods. For example, increasing milk production using the hormone Bovine somato-tropin (BST), cloning cows that produce high milk or beef stock. In 2008, the FDA approved sale of beef and milk from cloned cattle (Jaffe, 2012).

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4.0 THE CONTROVERSIES

The fact that conflicting information is given about GMOs and also because their benefits, risks and limitations have not been fully substantiated by various scientific, commercial, consumer and public organisations, has led to global controversy about the safety of consuming GMOs as food and that of releasing them into the environment (Ponti, 2005). The proponents of GMOs maintain that the technology holds tremendous benefits which include enhanced crop protection, increased productivity and improvements in food processing. This can be gathered from the kinds of traits engineered into both crops and animals. This has raised opposition from opponents who view consumption of GMOs as akin to poisoning people and the environment and the companies are only concerned with the profit. However the companies argue that modern agriculture needs to be improved and why would they want to produce poison and release to humans. Why do people take penicillin which is an antibiotic, why cheese, beer etc. The areas of controversy are mainly three: health, environment and socio-economic issues. Religious and ethical issues are also part of the argument.

Health Issues

Perhaps the most serious criticism of GMOs is their impact on health and well-being of human beings. The GMOs that have caused little or no controversy are those products that are used in the healthcare and industry such as insulin, hepatitis vaccine, food additives and food processing (Kelemu *et al*., 2003). The proponents of engineered foods argue that GMOs are safe and do not pose any health risks to human health as there are no such risks documented that are linked to GMOs. They argue further that there is no evidence to suggest that genetic modification has greater risks than crossbreeding and gene-splicing through which products like tangelo and seedless grapes are obtained. They hold the view that future innovations in the field have potential to improve human health and nutrition through development of new crop varieties with higher nutritional content. An example is the golden rice which was modified to have high amounts of β-carotene to help combat vitamin A deficiency (Paine *et al*., 2005). It is envisioned that researchers will move beyond nutritional content to disease prevention and treatment; for instance, there is on-going effort to engineer potatoes to contain vaccines for malaria and hepatitis and bananas to act as malarial prophylactic for distribution in malarial –infested areas (Zerbe, 2008).

The critics of the technology, however, are of the opinion that the potential risks of GMOs far outweigh the benefits. Most engineered crops produce new proteins which could be toxic and this makes it possible that new allergens could be present in a GE plant because allergies are caused by proteins. For example, bean plants that were genetically modified to increase cysteine and methionine content were discarded after the discovery that the expressed protein of the transgene was highly allergenic (Bawa and Anilakumar, 2013). Some opponents of GMOs consider the rise of diseases that are resistant to treatments with common antibiotics associated with them (Beluch, 2005: Jaffe, 2012). According to Steinbrecher (1996), the potential risks accompanied by disease resistant plants is mostly associated with viral resistance. Viral resistance may result in the formation of new viruses and hence new diseases. It has been reported that naturally occurring viruses can recombine with viral fragments that are introduced to create transgenic plants to form new viruses.

Environmental Issues

The pro- GMOs maintain that growing herbicide- tolerant crops results in reduction in pesticide use and hence less pesticide accumulates in food and ground water. The hazard of exposure of farmers to pesticide is also minimised. For instance, the use of Bt cotton has substantially reduced the use of highly poisonous insecticides in USA, China, India and other countries (Wieczoreck, 2003; Jaffe, 2012). Tillage which is one of the major causes of soil erosion as a result of loss of top soil is also reduced by GE technology because it allows built-in weed control as opposed to weed control through tillage (Savindo *et a*l., 2006). The opponents of GE crops, however, insist that GE crops could harm the environment in different ways.

a. Impact on non- target organisms

The GE crops could produce substances that kill non- target species such as beneficial insects like honey bee, birds or other organisms above or below ground. For example, researchers at Cornell University observed that pollen from corn genetically engineered to express insecticidal Bt toxin could kill caterpillars of Monarch butterfly under laboratory conditions. However, when the study was followed up in the field it was shown that butterfly from caterpillars are not likely to come in contact with pollen from Bt corn (Wieczorek, 2003; Jaffe, 2012). Allison and Palma (1997) reported that from toxicological standpoint, further investigation is required to determine if residues from herbicides or pest-resistant plants could harm important groups of organisms that inhabit the soil, like bacteria, fungi, nematodes and other microorganisms.

b. "Volunteer" crops

Genetically Engineered crops could spread and grow where they are not wanted; for instance, as "volunteer" crops and the "volunteer" is an herbicide- resistant variety, and there may be fewer herbicides to control it. This happened with some herbicide-resistant canola in Canada. The "volunteer" crops have now become weeds and would have to be controlled by other measures (Jaffe, 2012).

c. Potential gene escape and "super" weeds

In the event of cross pollination between GE and their wild relatives, it is likely to result in "super" weeds that become difficult to control thereby polluting the environment. This could cause serious problems with regards to crops engineered to produce pharmaceutical drugs because they can become cross breed with food crops. Pollen transfer from glyphosate resistant crops to related weeds can confer resistance to glyphosate. While the chance of this happening is small, still if it does the weeds could be controlled with other herbicides according to the proponents (Wieczorek, 2003). In a study in Mexico in 2001, it was reported that genes from genetically engineered maize contaminated the wild maize in Mexico by cross-pollination (Quist *et al.*, 2001; Cleveland, 2005). However, further studies have failed to show more examples of transgene spread in Mexican maize (Ortiz-Garcia *et al*., 2005).

d. Insecticide and herbicide resistance

There is concern that the use of Bt crops will in a period of 3-5 years lead to resistance to the toxin in pests and weeds, that is, insects may develop resistance to Bt crops, and weeds that are resistant to glyphosate may emerge. If this happens, then Bt toxin will no longer be effective as a pesticide. The insect repelling properties of GM foods may thus result in the evolution of insecticide-resistant pests, causing the accelerated evolution of "super pests"(Beluch, 2005; Bawa and Anilakumar, 2013). It is also possible that with increased death in a particular pest, due to the insect- resistant plant, there will be decrease in competition and secondary pests may become more prominent (Bawa and Anilakumar, 2013). This is due to the targeted control of the primary pest because Bt crops specifically target the primary pest; therefore, other measures have to be used to control the secondary pest. Those in support of the technology, however, argue that the issues related to insect resistance are not new or unique to GE crops. Even in the other conventional practices many weeds and insects have evolved resistance to pesticides and more toxic pesticides were needed to control them (Wieczorek, 2003).

Socio- economic Issues

a. Labelling

Labelling is a consumer right as consumers have the right to make a choice regarding GMOs, so it is not just about health issue (Maghari and Ardekani, 2011). Foods derived from GE crops that are currently sold in some countries like the United States, Canada and Argentina (which are big producers of GMOs) do not carry labels. Even though some consumers protest against this but according to the law in United States, for example, only foods that have different nutritional constitution from the conventional food will be labelled (Wieczorek, 2003). However, some countries have stringent regulations about labelling like the European Union (Wieczorek, 2003; Bawa and Anilakumar, 2013). People want transparency and consumer choice and believe that compulsory labelling of GM ingredients is highly required. The opponents of labelling, on the other hand, believe that it will make consumers reluctant to use engineered foods and it may also hold back progress on the technology as well as lead to increase in costs and logistical difficulties (Maghari and Ardekani, 2011).

b. "Terminator" seeds

Seeds that are harvested from GE crops cannot be saved and re-planted the following year. These "terminator" seeds are genetically engineered to prevent farmers from re-planting them. Consequently, the giant companies have monopoly of the technology (Wieczorek, 2003). This Terminator technology is regarded as a threat to farmers, biodiversity and food security (Gibbs, 2000). The US Department of Agriculture and Delta and Pine Land Company patented the 'Terminator' technology for seeds in 1998. A killer 'transgene' is introduced that prevents the germ of harvested grains from developing, such that while the plant grows normally, the grain is biologically sterile. Monsanto bought the Delta and Pine Land Company and the Terminator patent in 1998 but was forced to abandon the development of the initial Terminator technology due to public outcry over the implications. Several bioscience companies have, however, continued research into "Terminator[2] technology where genetic traits within seeds are controlled by proprietary chemicals. With these technologies, it means that crops will only grow if they are sprayed with such proprietary chemicals (Gibbs, 2000). Such a technology could harm farmers.

5.0 GMOs IN AFRICA

Africa has been a central focus for debate over the technology. There is nearly 30 years of history of collaborations among the agribusiness industry, US Government agencies, philanthropic organisations and African research councils to develop GMOs for African farmers. These collaborations have so far resulted in few GMOs reaching African farmers and markets. This may be due to widespread distrust of the technology and its developers, the issue of ownership, control and safety of GM foods. Another issue has to do with the complex nature of the public-private partnerships (PPP) that donors have set out to develop GM foods for the African continent. The GM technology is mainly owned and patented by few multinational corporations, and are, therefore, not readily accessible to African scientists and small to mid-sized African seed companies without a partnership agreement. Genetically modified (GM) crops have been commercially cultivated in four African countries of South Africa, Burkina Faso, Egypt and Sudan. Beginning in 1998, South Africa became the major grower of GM crops, with Burkina Faso and Egypt starting in 2008. Sudan grew GM cotton in 2012. Angola and Zimbabwe prohibit cultivation but allow imports of GMO products. Malawi and Eswatini have recently approved commercial release of GMOs. Other countries like Mozamque and Tanzania are conducting trials and research on crops important for Africa with the aid of international governments and foundation (Muzhinji and Ntuli, 2021). Crops under research for use in Africa include cotton, maize, cassava, cowpea, sorghum, potato, banana, sweet potato, sugar cane, coconut, squash and grape. Apart from disease, insect and virus resistance, some of the research projects focus on traits particularly crucial for Africa like drought resistance and biofortification (Zerbe, 2008). Ghana attempted to become a regional leader in biotechnology and wanted to be the first in West Africa to produce GM foods. In 2013, it approved the field trials of six GM crops including sweet potato, rice, cowpea and cotton. However, the project came across problems; funding for the sweet potato was exhausted soon after it began. The cotton research project was placed on hold in 2016 after Monsanto, which had been supplying the funding and Bt cotton seeds withdrew from the partnership. This was because there was no intellectual property rights. The Ghanaian activists actually opposed it after it has been debated by the parliament. The rice project also had its funding reduced by the main donor, USAID forcing them to reduce the scope of the rice projects due to insufficient funding. Meanwhile, in

Burkina Faso, Monsanto's Bt cotton started producing inferior lint quality and the company became embroiled in legal cases. Such difficulties as experienced by Ghana and Burkina Faso indicate how difficult it is to bring agricultural biotechnology to Africa.

A major problem that has become a source of concern is the development of regulatory frameworks for agricultural biotechnology generally. The commercial release of GM crops for cultivation requires the approval of biosafety regulatory regimes. A number of countries have commenced field trials of GM crops but only a few African countries have biosafety regulations in place. By 2006 countries that have started field trials in addition to South Africa include Benin, Burkina Faso, Egypt, Kenya, Morocco, Senegal, Tanzania, Zambia and Zimbabwe. Nigeria, Cameroon, Ghana, Malawi, Mali, Mauritius, Namibia, Niger, Tunisia and Uganda were actually engaged in some kind of GM research. Out of these countries only five (Egypt, Malawi, Nigeria, South Africa and Zimbabwe) had biosafety regimes in place, whereas Benin, Burkina Faso, Mali and Niger do not have even a draft legislation (Zerbe, 2008). Regulatory frameworks are necessary as they are developed to ensure a safe and plentiful food supply. The goals include protecting human health and safety, protecting flora, fauna and environment, addressing ethical and cultural concerns, providing for adequate consumer information meeting international trade and other obligations and protecting intellectual property rights (Zerbe, 2008).

In 2010, after nine years of talks, the Common Market for Eastern and Southern Africa (COMESA) produced a draft policy on GM technology, which was sent to all 19 national governments for consultation in September 2010. Under the proposed policy, new GM crops would be scientifically assessed by COMESA. If the GM crop was deemed safe for the environment and human health, permission would be granted for the crop to be grown in all 19 member countries, although the final decision would be left to each individual country (Akinbo *et al*., 2021).

In 2002, Zambia rejected genetically modified food (mostly maize) aid from UN's World Food Programme. This left the population without food aid during a famine (Zerbe, 2008; Cooke and Downie, 2010). In December 2005 the Zambian government changed its position in the face of further famine and allowed the importation of GM maize. However, the Zambian Minister for Agriculture, Mundia Sikatana, insisted in 2006 that the ban on genetically modified maize remained, saying "We do not want GM foods and our hope is that all of us can continue to produce non-GM foods" (Cooke and Downie, 2010). ECOWAS is currently drafting regulation on the adoption of an Action Plan for the Development of Biotechnology and Biosafety in the ECOWAS region (Akinbo *et al*., 2021).

GMOs in Nigeria

Nigeria made history in 2019 with the commercial release of insect- resistant cowpea, Sampea 20-T following approval by the National Varietal Committee, beating Ghana to permit the first GM food in West Africa. Sampea 20-T is the first GMO cowpea variety in the world, resistant to pod borer and the seeds can be made available to farmers. It was developed through multiple partnerships: private sector donated the Bt genes; Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia provided the technology for transforming cowpea; CSIRO in collaboration with National Agricultural Research System (NARS) of Ghana, Burkina Faso and Institute for Agricultural Research (IAR) of Nigeria were involved in product development; African Agricultural Technology Foundation (AATF) served to bring the partnership together and negotiated the intellectual property rights transfer (Akinbo *et al*., 2021).

Nigeria enacted a biosafety law, the National Biosafety Management Agency and it mandated the National Biosafety Management Agency (NBMA) to, among other objectives, provide a holistic approach for the regulation of GMOs. The NBMA was established in 2015 by an act under the Federal Ministry of Environment. The act was amended and passed as a law by the 8th National Assembly in 2019. GMOs are regulated by two agencies in Nigeria: NBMA and National Biotechnology Development Agency (NABDA). The mandate of NABDA concerns biotechnology policy, while that of NBMA focuses on the biosafety regulations of biotechnology- derived products. Nigeria commercialised two Bt cotton varieties, MRC 7377 BG 11 and MRC 7361 BG 11 in 2018 (Akinbo *et al*., 2021).

6.0 THE DILEMMA OF AFRICAN COUNTRIES

It has been projected that world population will increase to 12 billion by 2050 (Thies and Devare, 2007). In Africa, the projection is 1.7 billion people as reported by Kelemu *et al*. (2003). The most recent projection is 2.4 billion according to an online statistics (Goldstone, 2019), indicating that the figure is changing rapidly. This is at a time when agriculture is facing enormous challenges from lack of sophisticated farming tools, to rural -urban migration, scarcity of water and nitrogen, insufficient fertilizer, post- harvest losses, climate change and various forms of insecurity. Consequently, 790 million people are suffering from malnutrition and hunger. Many of these low-income food-deficit developing countries (LIFDCs) have difficulties to either produce sufficient food to feed their own populations or the foreign exchange reserves to import food to meet the deficits. To compound the problem, large international companies also have their eyes on Africa because of its potential to become the breadbasket of the world due to its highly fertile land. They are grabbing land from small farmers and putting them out of job with the support of the Governments as in Mozambique. In Mozambique, thousands lost their farms to a Chinese company, Wanbao Africa Agricultural Development Company, without compensation even though the company claims it is training farmers to grow rice (Bourne, 2014). Mozambique is not the only country in Africa where this is happening; other countries that have leased lands to foreign countries include Sudan, Ethiopia and Mali and it is gradually spreading. Sadly, the corporations export most, if not all, of their products abroad and the host countries end up not benefiting from the large- scale production (Midling, 2011). Could this lead to another imperialism – colonisation through agriculture?

With regards to the consumption of GMOs, many people are apprehensive because they feel that the dangers of consuming such foods are not known including the potential long-term effect since they have not been investigated on humans. The primary health concern associated with GE foods is the production of new allergens or toxins or increased level of naturally occurring toxicants or allergens found in crops. It may result in new harmful substances produced by the plant (Jaffe, 2012). There is also concern that new antibiotic resistant strains of bacteria will emerge from the antibiotic resistant genes that are used to identify and trace a trait of interest that has been introduced into the plant cells in order to ensure that a gene transfer is successful.

While these fears may be irrational, they are not unfounded when the incidences from history are examined. The revealed effect of the drug Thalidomide which has for long (1050s to 1960s) been prescribed to women to help them with morning sickness is now associated with birth defects. Then there is the incidence of the mad cow disease. Even though there is no relationship with genetic modification, such experiences have created fear and anxiety with respect to consumption of GMOs on health ground. The Zambian President, Levi Mwanawasa, refused to accept donation of GM maize from United States when they had a famine in the country suggesting they had rather die than be poisoned. He said "simply because my people are hungry that is no justification to give them poison, to give them food that is intrinsically dangerous to their health". The Government took a decision to adopt the precautionary principle on the matter. Similarly, governments of Malawi, Mozambique, and Zimbabwe after the initial rejection of the GM maize, eventually agreed to accept it after it had been milled to prevent possible mingling with domestic crop varieties (Cooke and Downie, 2010). This further indicates that the debate over GMOs in Africa remained unresolved (Zerbe, 2008).

The environmentalists also nurse similar anxiety concerning the impact of GMOs on the environment and biodiversity. Any harmful effect on the environment through large-scale cultivation of GM crops can affect human health. The dilemma of African countries concerning GMOs could thus be approached from the three main areas of controversy outlined above, that is, health, environmental and social.

Seeds that are harvested from GE crops cannot be saved and re-planted the following year because of the manner they were engineered. The term, "terminator" seeds is used to describe such seeds. This implies that farmers will have to buy the transgenic seeds every time they are planting. Consequently, the giant companies have monopoly of the technology (Wieczorek, 2003). The dilemma here is that of ensuring sustained availability of the seeds to farmers. How do the seeds reach the teeming small scale farmers who are used to storing a portion of their produce to use as seeds the following year? Another issue related to that is that of affordability, can they afford to purchase the seeds every year? This is bearing in mind that to date the African countries are struggling to make fertilizer available to farmers at affordable rates without much success. Again, will they make substantial profit considering their small farm sizes? Can GMOs co- exist with the local varieties?

Another issue of concern is that of labelling which is not just about health issue but a consumer right as consumers have the right to make a choice regarding GMOs. Why is labelling a problem, if there are no issues with GMO's? Some countries have stringent regulations about labelling like the European Union, while other countries like the U.S, Canada and Argentina, which are big producers of GMOs, do not observe these regulations (Wieczorek, 2003). The outcome of surveys commissioned by various organisations have shown that people are seeking for transparency and consumer choice and believe that compulsory labelling of GM ingredients is highly required (88% Canadians, 92% Americans and 93% French)(Maghari and Arrdekani, 2011). The opponents of labelling, on the other hand, believe that it will make consumers reluctant to use engineered foods and it may also hold back progress on the technology as well as lead to increase in costs and logistical difficulties (Maghari and Ardekani, 2011).

Another dilemma for African countries concerns that of the regulatory frameworks. The frameworks developed so far follow either the science policy or the precautionary principle. Cameroon, Egypt, Mozambique, Nigeria, Uganda and Zimbabwe have followed the precautionary principle, while Ghana, Kenya, South Africa, and Tanzania have developed their regulatory models based on the principle of sound science. The intellectual property rights also poses concerns that GMOs may substitute traditional varieties and that will make farmers dependent on private seed companies like Bayer, Syngenta and Corteva (Muzhinji and Ntuli, 2021).

7.0 THE WAY FORWARD

Africa has had a long history of developing and adopting agricultural policies with a view to charting the way to sustainable agricultural production for its large population. Even the green revolution of the 1980s has not had much impact on the agricultural development of the continent and Africa is still far from becoming self-sufficient. Food is still being imported, fertilizer is inadequate and very little irrigation is practised. Majority of Africa's populace remain subsistence farmers while mechanised farming is the privilege of a few wealthy farmers and improved crop varieties are not readily available. This is at a time when yield is declining due to pre- harvest and post- harvest losses caused by pests and diseases, water and nitrogen are limiting, climate is changing and there is demand for higher nutrition. At the same time, Africa's population is increasing at the rate of 2% and is expected to double by 2050 from 1 billion to nearly 2.4 billion and half of that population will be under 25 years old (Goldstone, 2019). Therefore, the issue of food security should be of paramount importance if hunger, malnutrition and poverty are to be overcome. Already, many countries are recipients of food aid and this is expected to rise due to the threats of droughts. Consequently, African countries will need to develop and implement strategies for increasing agricultural production in order to achieve food security. Genetic engineering is a modern technology that can provide improved crop varieties faster than the conventional breeding techniques. Already, African countries have begun to accept and introduce GMOs into the continent but more so as consumers of the technology as the countries, apart from South Africa, are not engaged in the commercial production of any of the products. With globalisation, it is easy for the products of biotechnology including GMOs to spread into the continent. Processed foods such as cornflakes, canned foods including corn have been on store shelves for ages. The more recent ones include canola oil, raw foods, fruit vegetables, grains, meats, fish and dairies. These foods don't carry a label to indicate whether they are from GMOs. With shopping malls on high rise due to development the challenge is distinguishing between GMOs and conventional foods.

African countries will need to be conversant with the technology and will, therefore, need to overcome the challenges that make it difficult for them to adopt the technology. These include lack of knowledge of the new technology, lack of professionals, sophisticated equipment, political will, financial resources and ethical concerns.

Therefore, developing GMOs in Africa for now will depend on a multitude of factors, including donor support, industry partnerships, research outcomes, policy change and societal acceptance. This is because presently there are insufficient public and private investments and absence of relevant infrastructure for the delivery of the technology. The right policies are also not in place. The benefits of biotechnology can only be realised when knowledge of the technology becomes available and the continent develops appropriate policies that will facilitate the development and utilisation of both human and financial resources as well as the requisite infrastructure and functioning support institutions (Sere and Rege, 2007).

So far the developed countries led by the United States have monopoly of GE technology which is associated with risks. Africa differs from the industrialised countries. Apart from South Africa, none of the countries can afford the technology on commercial level, nor can they afford to adequately establish the testing and regulatory systems that can assure the safety of GMOs. The fact that in Africa agriculture remains mostly subsistence on small farms and farmers save seeds for next farming season, private sector may not be willing to focus its attention to take on research on the problems of small holder farmers because it may not be profitable. Their focus will rather be on industrialised nations and large-scale farming systems who can readily afford it (Sharma *et al*., 2002). It becomes imperative for African scientists to have access to the knowledge and scientific infrastructure to be able to carry out relevant research on GMOs that will address problems of African farmers, manage the risks and set the regulatory laws which are highly needed due to the risks. It is also important to have professionals who can engage in public enlightenment on the potentials and challenges of the technology. This is because open public discussions will most certainly play a significant role in defining the role biotechnology will play in the society as the technology continues to evolve.

There is the need for the scientists to engage in competitive and international collaborative researches that will lead to breakthroughs in the cross- cutting technology in order to gain from its benefits. Consequently, there is the need for intensive education and capacity-building. African continent with its large population, high level of poverty and food insecurity will end up as the greatest consumers of the product of the technology. It is, therefore, imperative for African researchers to also compare the benefits and costs of producing GMOs with local farmers' varieties and conventionally improved varieties and even organic varieties, in order to best determine the potential of GMOs to the farmers.

Religious groups also have ethical concerns about GMOs. For example, because the gene can come from any living organism, Muslims are sceptical about foods that have been modified using a gene from pig. Just recently, in 2014, there was widespread information that circulated over the social media warning Muslims not to consume a certain chocolate manufactured in Malaysia because it was indicated in its label that it contains a substance that was obtained by genetic modification using the gene of pig. Consequently, religious groups have to address such ethical challenges and to be able to do so they will need to be enlightened about the technology. There is, therefore, the need for African countries to develop their own capacity for this technology to accommodate their specific needs and address their peculiar problems.

CONCLUSION

Genetically Modified Organisms are developed through biotechnology and often carry genes from bacteria or virus and they have been in use for many years. Even though from scientific consensus they are considered safe to eat and present no risk to the environment, their development and use have generated a lot of controversy the world over including Africa. However, considering the population size of Africa and the multitude of challenges facing its agriculture, the need to double or even triple food production cannot be over emphasised. Africa is approaching availability limits for land and resources when competing demands for food, feed, fuel and fibre and forest are considered. While GMOs alone cannot substitute for other technologies just like organic and inorganic farming or conventional breeding cannot individually sustain the agricultural needs of the nation, it offers tremendous potential if it is closely examined. However, it is important to address the health, environmental and socio-economic issues for public acceptance. Throughout history, technology has had beneficial impact on nation's economies and in improving the lives of people and although some technologies faced initial rejection by people they although were eventually accepted. Similarly, although GMOs are currently facing strong opposition from its opponents, they continue to grow. Should Africa sit back and watch while biotechnology takes over information technology in the next few years as it is envisaged and end up only as consumers of the product of the technology, or should it be part of its growth? Certainly, the technology cannot provide the whole solution to food insecurity in Africa neither can it take root in the nearest future because of its high demand on human and financial resources and due to the multitude of other challenges including small farm sizes. So the continent can consider adopting the best practices of the technology that are easily available for implementation for now. In the meantime, the countries in Africa should invest in training of their people on the technology and on training and research collaborations and partnerships. This will facilitate getting professionals in the technology who can conduct researches on GMOs while targeting specific needs of African farmers and consumers. They can also enlighten the people on the benefits of GMOs. For now research efforts should be geared towards enhancing the effectiveness of the other practices through integrated pest and disease control, stress tolerance, nutrient management, biofuel, forestry and conventional breeding. Improved crop varieties should be made adequately available to farmers and farming transformed into mechanised form. Conventional hybrid seeds that have good yield potentials are widespread in Africa but they are not sufficient for farmers. If they can be used with good agronomic practices and appropriate fertilizers, Africa may not need GMOs in the near future. As Ghana's Minister for Food and Agriculture, Owusu Afriyie Akoto, said, he too believes that hybrid seeds could provide a more workable solution than GM." GMO for me is like cracking a little nut with a sledge hammer. We have so many varieties of a whole range of crops developed through traditional breeding methods by our scientists, sitting on the shelves in their universities and research organisations. We haven't even touched 20% of them." He further said," the focus should be to use and maximise what we have, instead of chasing something else (Kedem, 2019)." I believe the same applies to many African countries. Ultimately, with knowledge and public awareness, Africans would make informed decision on whether the potentials of biotechnology as a means of enhancing agricultural development and even other sectors like health and the industry deserve a chance just like the transport and communication technologies.

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