BREEDING GENETICALLY MODIFIED ORGANISMS: THEIR BENEFITS, ISSUES AND REGULATIONS IN NIGERIA

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ABSTRACT
Genetic modified organisms (GMOs) have become a controversial topic as their benefits for both producers and consumers are associated with potential biomedical risks and environmental hazards. Increasing concerns from Nigerians about GMOs, particularly in the form of genetic modified (GM) foods, are aimed at the short-and long-lasting health problems that may result from this advanced biotechnology. In this paper, we attempt to explore the benefits, potential risks (issues) of GM food and safety measures in the application of modern biotechnology in Nigeria with a view to preventing any adverse effect on human health, animals, plants and environment.

Keywords: Genetic modified organisms, benefits, human health, potential problems, biosafety, biotechnology, Nigeria.

INTRODUCTION

During the Twenty-Third Ordinary Session of the African Union Assembly in Malabo, Equatorial Guinea, the Heads of States and governments of Africa undertook to eliminate hunger on the African continent by the year 2025. Nigeria is a signatory to the Malabo declaration but as at date, 10 percent of the nation's population is still unable to meet their daily calorific needs due to unaffordability, ineffective mass food production, storage and distribution problems. Developing countries of the world (such as Kenya, Ghana, Cameroon, etc.) faced with similar challenges have attempted to address them using new technologies especially biotechnology (Table 1).

Figure1: On-going Biotech/GM Crops Research Activities in Africa

Sudan	Cotton, Gossypium hirsutum L.	Insect resistance 2 Indian Bt hybrids 1 Chinese Bt cotton variety SCRC37	Biotechnology and Biosafety Research Center; China-aid Agricultural Technology Demonstration Center, Elfaw	Multi-location trials completed for 3 additional Bt hybrid varieties; Approved for commercial planting
Nigeria	Cowpea	Insect resistant to Maruca pest	AATF, Institute of Agricultural Research	Back crossed, 2nd season Multi-locational trials in 3 sites managed by farmers
	Sorghum (ABS)	Biofortification	Africa Harvest, Pioneer Hi-Bred, a company of DuPont business, IAR and NABDA	4th CFT and back crossing with preferred Nigerian varieties, still on going
	Rice	Nitrogen use, Water efficient and salt tolerant (NUWEST) Rice	National Cereals Research Institute, Badeggi	Permit granted trial in on going
	Maize, Zea mays	Insect resistance Bt + Herbicide tolerant HI corn	Monsanto Agriculture Nigeria Ltd	CFT permit granted (yet to commence)
	Cotton (commercial released)	Insect resistance	Monsanto Agriculture Nigeria Ltd	Approved for commercial release: Bt Cotton (On 4 multi-location NPTs)
Ethiopia	Cotton	Insect resistance	Ethiopia Institute of Agricultural Research (EIAR), JK Agri Genetics India	Multi location trials in 6 sites
Ghana	NUWEST rice	Nitrogen Use Efficiency/Water Use Efficiency and Salt Tolerance	Crop Research Institute, AATF, IITA	3rd CFT relocated to a more drier area (uplands)
	Bt Cowpea	Insect resistance	AATF, Savannah Agricultural Research Institute	Multi-location trials planted in 3 sites
Cameroon	Cotton	Insect resistance and herbicide tolerance	Bayer Crop Science	Application for Environmental release in process
Kenya	Maize, Zea mays L.	Drought tolerance (WEMA)	AATF, CIMMYT, KALRO	CFT - 6th Season completed
		WEMA Insect resistance (Bt maize MON810)	AATF, CIMMYT, KALRO	Conditional Approval for Environmental release; to conduct National Performance Trials (NPTs)
		Stack maize event for Bt (MON810) and Drought (MON87460)	AATF, CIMMYT, KALRO	1st season CFT completed
	Cotton, Gossypium hirsutum L.	Insect resistance	KALRO, Monsanto	Conditional Approval for Environmental release; to conduct National Performance Trials (NPTs)
	Gypsophila, Gypsophila paniculata	Pink Colouration of Petals	Danziger - "Dan" Flower Farm, Israel	Review for Environmental release
	Cassava, Manihot esculenta Crantz	Cassava Brown Streak Disease introgression into CMD tolerant background materials	KALRO, Danforth Plant Science Center (DDPSC)	1st season CFT completed, Regulatory trial ongoing - 1st season
		Cassava Brown streak virus (CBSV) and African Cassava Mosaic Virus (ACMV)	Masinde Muliro University of Science and Technology (MMUST)	CFT - 1st season completed
	Sweet potato Ipomoea batatas	siRNA resistance to Sweet potato virus disease	KALRO-Kakamega, Danforth Plant Science Center (DDPSC)	1st season CFT completed
	Banana	Banana bacterial - Xanthomonas Wilt (BXW) resistance	KALRO, IITA	1st season CFT ongoing
	Sorghum (ABS), Sorghum bicolor Moench	Enhanced pro-Vit. A levels, Bio-available Zinc and Iron	Africa Harvest, Pioneer Hi-Bred, a DuPont business, and KALRO	CFT - 7th Season completed

Nigeria tops the list of eleven ECOWAS countries that have over one million people affected by hunger and undernourishment while 63 percent of the population lives below the poverty line of less than one dollar per day (Gidado, 2017).

The challenges are ample, which made Nigeria to resort to the rapid reduction in poverty and malnutrition through the expansion of farmland and the increase in yields through "conventional plant breeding".

Conventional plant breeding relies on sexual crossing of one parental line with another parental line, in hopes of expressing some desired property (e.g disease resistance and increased yield) (Oliver, 2014). To select for the desired trait and to discard irrelevant or undesired traits, breeders choose the best progeny and back-cross it to one of its parents (plant or animal) with the most desired trait with a viewing to capturing the trait of interest. The process usually takes several years (depending on generational time, e.g 10-15 years for wheat) before actual expression of the desired trait that can be assessed, and further expanded by conventional breeding to commercially useful numbers. Besides the inherently long generation times, the following facts limit the development of conventional breeding: pre requisite to breeding strategies is the existence of genetic variation that is, existence of an available gene-pool manifesting the desired traits, and sexual compatibility of organisms with those traits. Conventional plant breeding was still making very substantial contributions to growth in yield. But its effect was increasingly reduced by new types of pest, exhaustion of micronutrients, water shortages and unsuitability of land for important semi-dwarf varieties like in rice and wheat. There was overall exhaustion of the huge potential created by the early breakthroughs of the green revolution. The challenges of conventional plant breeding led Nigeria into growing and importing of genetically modified crops a very pervasive agricultural practice which in addition to, conventional plant breeding could make food abundant and available to the generality of the masses (Gidado, 2017).

However, the benefits of genetically modified crops for both producers and consumers are associated with potential biomedical risks and environmental side effects which have to be regulated properly by the National Bio-safety Management Agency (NBMA).

What are GMOs and GM Foods?

Genetic modification is a biological technique that affects alterations in the genetic machinery of all kinds of living organisms. GMO is defined as follows by WHO (World Health Organization); "Organisms (i.e. plants, animals or microorganisms) in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination". The World Health Organization definition of GMO seeks to distinguish the direct manipulation of genetic material from the millennial-old practice of improvement in genetic stock of plants and animals by selective breeding with DNA recombinant technology, genes from one organism can be transferred into another, usually unrelated, organism. For instance, a desirable gene from water melon can be transferred into cucumber thereby circumventing the conventional breeding process (Umeh *et al.,* 2017). Similarly the Food and Agriculture Organization of the United Nations and the European Commission define a GMO as a product "not occur naturally by mating and/or natural recombination" (FAO, 2016). Therefore, "GM foods" refer to foods produced from genetically modified plants or animals, example of GM foods is shown in Table 2. Triticale is a grain widely used in bread and pasta. It was developed in 19th century by crossing wheat with rye (a conventional selective breeding approach) however, the resulting hybrid is sterile and in the 1930s, the chemical colchicine was used to generate polyploidy embryo cells, which are fertile. Triticale would seem unambiguous to fit the definition of a GMO, even if the genetic modification is somewhat primitive by current molecular biological standards (Oliver, 2014). Thus Oliver (2014) suggested "biotechnological modified organisms" as a closer definition for GMO.

Table 2: Examples of GM Foods and Mega- Countries producing them.

Rank	Country	Area (million hectares)	Biotech Crops
1*	USA*	62.5	Soybean, maize, cotton, canola, squash, papaya, alfalfa, sugarbeet
2*	Argentina*	21.0	Soybean, maize, cotton
3*	Brazil*	15.8	Soybean, maize, cotton
4*	India*	7.6	Cotton
5*	Canada*	7.6	Canola, maize, soybean, sugarbeet
6*	China*	3.8	Cotton, tomato, poplar, petunia, papaya, sweet pepper
7*	Paraguay*	2.7	Soybean
8*	South Africa*	1.8	Maize, soybean, cotton
9*	Uruguay*	0.7	Soybean, maize
10*	Bolivia*	0.6	Soybean
11*	Philippines*	0.4	Maize
12*	Australia*	0.2	Cotton, canola, carnation
13*	Mexico *	0.1	Cotton, soybean
14*	Spain *	0.1	Maize
15	Chile	<0.1	Maize, soybean, canola
16	Colombia	<0.1	Cotton, carnation
17	Honduras	<0.1	Maize
18	Burkina Faso	<0.1	Cotton
19	Czech Republic	<0.1	Maize
20	Romania	<0.1	Maize
21	Portugal	<0.1	Maize
22	Germany	<0.1	Maize
23	Poland	<0.1	Maize
24	Slovakia	<0.1	Maize
25	Egypt	<0.1	Maize

* 14 biotech mega-countries growing 50,000 hectares, or more, of biotech crops
Source: Clive James, 2008.

Why GM Foods?
Before discussing the benefits, potential risk (issues) of GM foods and how National Biosafety Management Agency (NBMA) should apply its regulatory for safety measures, it is important to set forth why there is such great effort to develop genetically modified crops in Nigeria. The major challenges that motivated government resort to the new technology for help is:

Expansion of Population
The 2018 population estimate for Nigeria was 195, 875,237 with male population of 104,141,237 and female population of 91,734,000 and population density of 215 per square kilometer.

Table3: Population of Nigeria (2018 and historical)

Year	Population	Yearly % Change	Yearly Change	Migrants (net)	Median Age	Fertility Rate	Density (P/Km²)	Urban Pop %	Urban Population	Country's Share of World Pop	World Population
2018	**195,875,237**	2.61 %	4,988,926	-60,000	17.9	5.67	215	48.9 %	99,967,871	2.57 %	7,632,819,325
2017	**190,886,311**	2.63 %	4,896,671	-60,000	17.9	5.67	210	50.2 %	95,764,092	2.53 %	7,550,262,101
2016	**185,989,640**	2.65 %	4,807,896	-60,000	17.9	5.67	204	49.3 %	91,668,667	2.49 %	7,466,964,280
2015	**181,181,744**	2.70 %	4,520,697	-60,000	17.9	5.74	199	48.4 %	87,680,500	2.45 %	7,383,008,820
2010	**158,578,261**	2.68 %	3,927,757	-60,000	17.9	5.91	174	43.8 %	69,440,943	2.28 %	6,958,169,159
2005	**138,939,478**	2.58 %	3,317,494	-34,000	18.0	6.05	153	39.3 %	54,541,496	2.12 %	6,542,159,383
2000	**122,352,009**	2.52 %	2,868,109	-19,005	17.9	6.17	134	35.0 %	42,810,252	1.99 %	6,145,006,989
1995	**108,011,465**	2.54 %	2,548,295	-19,154	17.7	6.37	119	32.3 %	34,918,670	1.88 %	5,751,474,416
1990	**95,269,988**	2.64 %	2,331,338	-18,281	17.4	6.60	105	29.8 %	28,379,229	1.79 %	5,330,943,460
1985	**83,613,300**	2.62 %	2,030,515	-134,328	17.5	6.76	92	25.7 %	21,508,164	1.72 %	4,873,781,796
1980	**73,460,724**	3.00 %	2,017,430	170,930	18.0	6.76	81	22.0 %	16,191,472	1.65 %	4,458,411,534
1975	**63,373,572**	2.51 %	1,478,434	-7,705	18.3	6.61	70	19.8 %	12,573,568	1.55 %	4,079,087,198
1970	**55,981,400**	2.23 %	1,170,837	-8,669	18.7	6.35	61	17.8 %	9,969,016	1.51 %	3,700,577,650
1965	**50,127,214**	2.12 %	997,880	674	19.1	6.35	55	16.6 %	8,315,202	1.50 %	3,339,592,688
1960	**45,137,812**	1.90 %	810,450	541	19.1	6.35	50	15.4 %	6,967,110	1.49 %	3,033,212,527
1955	**41,085,563**	1.65 %	645,164	674	19.1	6.35	45	11.1 %	4,541,081	1.48 %	2,772,242,535

Source: **Worldometers** (www.worldometers.info//), Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2017 Revision.

The world meters population (www.worldometers.info/world-population/nigeria-population), the famous tool for estimation of real-time population of countries globally estimated that Nigeria population had hit 195,875, 237 in 2018 moving towards having an estimated population of 410 million people in 2050. At conservative cost of N150 per plate of food per person per meal, a staggering amount of N116billion naira worth of food is required to feed this teeming population per day at 3.5 trillion Naira per month (Othman, 2017).

Nigeria Population Forecast

Year	Population	Yearly % Change	Yearly Change	Migrants (net)	Median Age	Fertility Rate	Density (P/Km²)	Urban Pop %	Urban Population	Country's Share of World Pop	World Population
2020	**206,152,701**	2.62 %	4,994,191	-60,000	18.1	5.42	226	52.7 %	108,711,170	2.64 %	7,795,482,309
2025	**233,691,888**	2.54 %	5,507,837	-60,000	18.5	5.08	257	56.7 %	132,547,150	2.85 %	8,185,613,757
2030	**264,067,527**	2.47 %	6,075,128	-60,000	19.2	4.74	290	60.3 %	159,240,806	3.09 %	8,551,198,644
2035	**297,323,173**	2.40 %	6,651,129	-60,000	19.9	4.41	326	63.4 %	188,612,714	3.34 %	8,892,701,940
2040	**333,172,092**	2.30 %	7,169,784	-60,000	20.7	4.10	366	66.3 %	220,824,256	3.62 %	9,210,337,004
2045	**371,119,359**	2.18 %	7,589,453	-60,000	21.5	3.81	407	69.1 %	256,584,400	3.90 %	9,504,209,572
2050	**410,637,868**	2.04 %	7,903,702	-60,000	22.4	3.55	451	72.0 %	295,479,827	4.20 %	9,771,822,753

Source: **Worldometers** (www.worldometers.info//) , Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2017 Revision.

Thus, the expansion of population is one of the major contributors to undernourishment in Nigeria. In 2016, the UN Food and Agricultural Organization (FAO) reported that 795 million people in the world were undernourished, among which 780 million people in developing regions FAO(2016). Countries under pressure to produce more food for their growing population have started growing genetically modified (GM) crops.

Table 4: Global Area of Biotech Crops in 2015 and 2016: by Country (Million Hectares)**

	Country	2015	%	2016	%	+/-	%
1	USA*	70.9	39	72.9	39	2.0	3%
2	Brazil*	44.2	25	49.1	27	4.9	11%
3	Argentina*	24.5	14	23.8	13	-0.7	-3%
4	Canada*	11.0	6	11.6	6	0.6	5%
5	India*	11.6	6	10.8	6	-0.8	-7%
6	Paraguay*	3.6	2	3.6	2	0	0%
7	Pakistan*	2.9	2	2.9	2	0	0%
8	China*	3.7	2	2.8	2	-0.9	-24%
9	South Africa*	2.3	1	2.7	1	0.4	17%
10	Uruguay*	1.4	1	1.3	1	-0.1	-7%
11	Bolivia*	1.1	1	1.2	1	0.1	9%
12	Australia*	0.7	<1	0.9	<1	0.2	29%
13	Philippines*	0.7	<1	0.8	<1	0.1	14%
14	Myanmar*	0.3	<1	0.3	<1	0	0
15	Spain*	0.1	<1	0.1	<1	0.1	0
16	Sudan*	0.1	<1	0.1	<1	0.1	0
17	Mexico*	0.1	<1	0.1	<1	0.1	0
18	Colombia*	0.1	<1	0.1	<1	<0.1	<0.1
19	Vietnam	<0.1	<1	<0.1	<1	<0.1	<0.1
20	Honduras	<0.1	<1	<0.1	<1	<0.1	<0.1
21	Chile	<0.1	<1	<0.1	<1	<0.1	<0.1
22	Portugal	<0.1	<1	<0.1	<1	<0.1	<0.1
23	Bangladesh	<0.1	<1	<0.1	<1	<0.1	<0.1
24	Costa Rica	<0.1	<1	<0.1	<1	<0.1	<0.1
25	Slovakia	<0.1	<1	<0.1	<1	<0.1	<0.1
26	Czech Republic	<0.1	<1	<0.1	<1	<0.1	<0.1
27	Burkina Faso	0.5	<1	–	–	–	–
28	Romania	<0.1	<1	–	–	–	–
	Total	**179.7**	**100**	**185.1**	**100**	**5.4**	**3.0**

* Biotech mega-countries growing 50,000 hectares or more
** Rounded-off to the nearest hundred thousand or more

Source: ISAAA, 2016

In 2016, global hectarage of biotech crops increased from 179.7 million hectares to 185.1 million hectares, a 3% increase equivalent to 5.4million hectares. Therefore, the eradication of hunger should be a priority of policy-making. Arguably, the most realistic solution for matching increased Nigerian demand for crops is to boost the crop yields on currently cultivated land. Currently, the rate of increase in crop-yield is less than 1.7% whereas the annual increase in yield needs to be 2.4% to meet the demands of population growth, improved nutritional standards and decreasing availability (Othman, 2017). This is a daunting task, which seems only achievable by means of optimization of crops genetics coupled with quantitative improvement in management of the agricultural system.

BENEFITS OF GM FOODS

Improvements in food processing

The GM technology can be employed to facilitate food processing. A notable achievement is *"FLavr Savr"* tomatoes. They were produced by the California company, Calgene, in 1992. The genetic alteration consists of introduction of an anti-sense gene which suppresses the enzyme polygalacturonase; the consequence is to slow down the ripening of tomatoes and thus allow longer shelf life for the fruits. The composition of potato bulbs has also been altered by gene editing. For instance, using a cyclodextrin glycosyltransferases gene from bacteria, potatoes exhibit greater stability of brightness factors and thus, a more attractive appearance (Oakes *et al.,* 1991).

Table5: Important Globally Approved Genetically Modified Plants

Product	Genetically Altered Traits
Tomato	Delayed ripening: Gene sequence for polygalaturonase production in tomato rearranged and reversed to minimise its expression by Antisense technology.
Cotton	Bt gene incorporated plants (ballworm & budworm resistant): CRY 1A c gene from Bt Kurstaki.
Soybean	Resistant to glyphosate for control of weeds: Enolpyruvylashikimate-3-phosphate synthase gene from Agrobacterium sp.CP4
Potato	Bt gene incorporated (Colorado potato beetle resistant) : Cry III (A) gene from Bt. Tenebrionis.
Maize/Corn	Bt gene incorporated (resistant to cornborer) : Cry 1A b gene from Bt. Kurstaki
Rapeseed / Canola	Altered oil composition (high lauric acid content): 12:0 acyl carrier protein thioesterase gene from Umbellularia californica. Resistant to glufosinate for Male sterility properties
Squash	Resistant to viruses: Coat protein genes of watermelon mosaic virus 2 and Zucchini yellow mosaic virus.
Papaya	Resistant to Papaya ring spot virus: Coat protein gene of p type of PRSV HA-5-1 from Hawai.
Chicory	Male sterility resistant to glufosinate and fertility restores genes from bacteria.

Source: ISAAA, 2016

Genetic modification is not limited to plants, but is also applied to animal products. Some researchers are exploring transgenic fish with a view to enhancing the generation of growth hormones to accelerate growth and body mass (Nicolia *et al*., 2014).
very recently the FDA (the US Food and Drug Admi nistration) approved the first genetically engineered a nimal)"Aqua Advantagea" Salmon-a fast- growing salmon-for human consumption in the United States. The decision was made after two decades of regulatory limbo. Because the fish grow to full size in 18 months, rather than 3 years, and with less demand for food resources per kilogram of harvested fish. Farming "Aqua Advantagea" may ease pressure caused by heavy fishing of wild populations (Chandler and Dunwell, 2008).

Products for Therapeutic Purposes

Genetic engineering techniques enable the expression of bacterial antigens in the edible portion of plant cells (Ellstrand and Hancock, 1999). In theory, transgenic foods could serve as oral vaccines, capable of stimulating the immune system, via mucosal immunity, to produce antibodies. A variety of crops (e.g. Rice, maize, soybean and potatoes) are under study as potential bearers of edible vaccines against different infections including *Escherichia coli* toxins, rabies, virus, *Helicobacter pylori* bacteria and type B viral hepatitis (Nicolia *et al.*, 2014).

Economic Benefits

From 1996 to 2016, the global increase in farm income from GM food reached US$167.8 billion, it is noteworthy that US $81.7 billion generated in Industrial Countries, almost triple that of previous 10 years (Brookes and Barfoot, 2017). According to the estimation from James and Brookes, about 42% of the economic gain was from the increased yield due to advanced genetics and resistance to pests and weeds. The decreased costs of production (e.g from reduced pesticide and herbicide usage) contributed the remaining 58%.

Agronomic Benefits

The period, 1996-2012 saw an increase of more than 370 million tons of food crops. One-seventh of the increased yield is attributed to GM crops in the U.S. to achieve an equal increase in yield as delivered by GM crops, it is estimated that an addition of more than 300 million acres of conventional crops would have been needed (Brookes and Barfoot, 2014; James 2013). These additional 300 million acres would necessarily be lands requiring more fertilizer or irrigation, or carved out tropical forests. Such conversion of land would generate serious ecological and environmental stress to the world. Brookes and Barfoot (2014) arrived at similar conclusions; for the period 1996-2013 they estimated that biotechnology was responsible for additional global production of

138 million tons of soybeans, 274 million tons of corn, 21.7 million tons of cotton lint, and 8 million tons of canola, if those biotechnologies had not been available, to maintain equivalent production levels would have required an increment of 11% of the arable land in the US, or 32% of the cereal area in the EU.

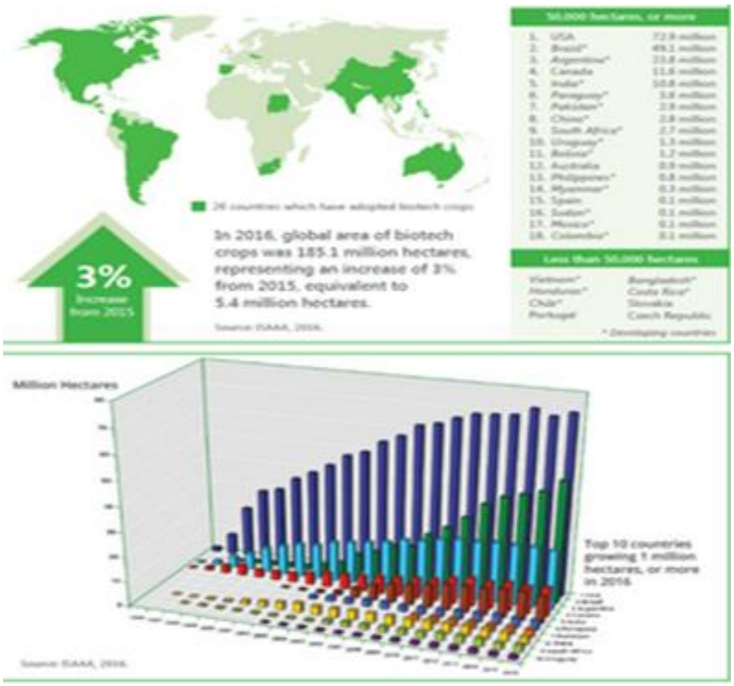

Figure 2: Global Area (Million Hectares) of Biotech Crops, 1996 to 2016, by Country

Potential Issues of GM Foods

Environmental issues: The various environmental issues which arise as a result of the increasing plant biotechnological research and the wide adoption of GM organisms are: Genetic erosion and biodiversity loss, Potential introgression, Contamination, Resistance emergence, Harm to other organisms and Resistance to antibiotics.

Genetic erosion and biodiversity loss: While some Nigerians see biotechnology as a great benefit; others see it as an interference with the laws of nature. There are reports that the wide adaptability of GM crops has contributed to plant genetic erosion and has decreased the biodiversity of plants and even animals.

Potential introgression: Transferred genes may escape and produce transgenic segments in the form of super weeds (giant weeds) or unwanted or unintended plant types.

Contamination or genetic pollution of indigenous varieties: The potential appearance of giant weedy relatives resistant to herbicides might cross pollinate GM crops or indigenous crops, polluting them. It is also believed that new diseases have emerged due to transgenic contamination.

Resistance Emergence: There are additional worries about the sustainability and durability of pest resistance as a result of the increasing and uninterrupted use for more than one decade of modified *Bacillus thuringiensis* toxins (Bt), which confer insect-resistance to GM crops (Baura and Anilakumar, 2013).

Harm to other organism: Non-targeted species may be inadvertently harmed by a genetically modified plant producing endo- toxins intended for a specific pest. The Bt endo-toxin is widely used by organic and conventional farmers because it is a relatively harmless, natural pesticide. However, genetically modified plants such as Bt corn, cotton, potatoes, rice and tomatoes constantly produce the Bt endo- toxin, and may speed up the spread of Bt resistance among pests that feed on these.

Resistance to antibiotics: Development of resistance to antibiotics is a scourge well known to medical science, and is traceable to the overuse of therapeutic antibiotics in medicine and agriculture. In the processes of genetic modification, antibiotics are also frequently employed, typically as selection marker, to distinguish successful transformed bacteria from those in which the transfecting genes did not take hold. Thus, the machinations to genetically modify an organism carries the risk of transferring the genes of antibiotics resistance into the benign bacteria comprising the microflora of human and animal gastrointestinal tracts, or, worse yet, to pathogenic bacteria harbored by the consumer of GM food, because bacteria, good or bad are quite capable of shuttling useful genes like those that protect them from nasty antibiotics around by horizontal transfer between species (Tabashnik, 1994; Ricroch *et al*., 2011).

Human Health Issues

Three major health risks potentially associated with GM foods are: toxicity, allergenicity and genetic hazards. These arise from three potential sources, the inserted gene and their expressed proteins per se, secondary or pleiotropic effects of the products of gene expression, and the possible disruption of natural genes in the manipulated organisms (Bawa and Anila, Kumar, 2013). "Starlink" maize provides an example of a food hazard caused directly by the expression of the inserted gene (Tabashnik, 1993). The modified plant was engineered with genetic information from *Bacillus thrringinesis* in order to endow the plant with resistance to certain insects. The insert gene encodes a protein called cry9c, with pesticidal properties, but with an unintended, strong allergenicity. Several cases have been reported of allergic reaction in consumers after consuming the "Starlink" maize.

Socio-Economic Issues

The major socio economic fear is the risk of patent enforcement which may oblige farmers in Nigeria to depend on giant engineering companies such as Monsanto for strains when their crops are cross-pollinated. Consumer advocates are equally worried that patenting these new plant varieties will raise the price of seeds so high that small farmers will not be able to afford seeds for GM crops, thus widening the gap between the wealthy and the poor. These plants would be viable for only one growing season and would produce sterile seeds that do not germinate. Farmers would need to buy a fresh supply of seeds each year, consequently will have to be dependent on the few agric-biotech companies with patent rights. However, this would be financially disastrous for farmers in Nigeria who cannot afford to buy seed each year and traditionally set aside a portion of their harvest to plant in the next growing season.

Safety Measures in the Application of Modern Biotechnology in Nigeria

In 2015, under the administration of Goodluck Ebere Jonathan, the bill for the establishment of the National Biosafety Management Agency (NBMA) was signed into law. The bill charged the agency with the responsibility for providing regulatory framework, institutional and administrative mechanism for safety measures in the application of modern technology in Nigeria with a view to preventing any adverse effect on human health, animal, plants and environment. However, with the potential risks posed by GMO, the present review suggests that; the agency in collaboration with the Ministries of Environment, Agriculture, Science and Technology, Trade and Investment, Health, Nigeria Custom Service, National Agency for Food and Drug Administration and Control (NAFDAC) and National Biotechnology Development Agency (NABDA) should:

i. Form a board with its sub-units (NBMA) located in every state of the country, their duty should be to move around the country and identify GMO products so as to ascertain their level of compliance.
ii. Label all internally and externally GMO products in Nigeria as to monitor smuggled GMO products.
iii. Thoroughly test every GMO product imported into the country. This will help to know the products that have potential risks on health and environment.

Conclusion

Genetically-modified foods have the potential to solve many of the Nigerian's hunger and malnutrition problems and help protect and preserve the environment by increasing yield and reducing reliance upon chemical pesticides and herbicides. There are many challenges ahead for the National Biosafety Management Agency (NBMA), especially in the area of safety testing, regulations, international policy and food labeling. Many people feel that genetic engineering is the inevitable wave of the future and that we cannot afford to ignore a technology that has such enormous potential benefits. However, we must proceed with caution to avoid causing unintended harm to human health and the environment as a result of our enthusiasm for this powerful technology. Nigeria is one of the leading producers of plantain, Okra, tomatoes, and the leading producer of yam and cassava but 30%-50% of these are lost due to poor post harvest practices. Hence, there should be maximum investment in storage technology in all federal constituencies, more production should be stimulated and wastages that occur due to hoarding should be checked.

Agricultural support programs and research institutes that have been put in place by the government should be spurred towards fully stepping up food production and do much more in the quest to store what is produced to minimize post-harvest losses. This will in the long run lead to the attainment of the much more desired eradication of hunger and undernourishment come 2025 in Nigeria.

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