AN EXTENSIVE REVIEW ON GENETICALLY MODIFIED (GM) FOODS FOR SUBSTANABLE DEVELOPMENT IN AFRICA

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ABSTRACT

Genetic modification (engineering) of crops is an extension of the age-old practice of cross breeding and selection to develop new crop varieties. With traditional breeding methods, thousands of traits from two crops are combined. Using genetic engineering only the desired characteristics are added to a plant. This technique holds a lot for Africa. Some of the benefits, Africa stands to derive include, Increased food production, improved nutritional and health benefits, improved environmental condition, improved economic benefits and improvement in fruit storage**.** Genetic modification technique allow for novel traits to be introduced into animals, crops and micro-organisms. These techniques can be used to improve livestock, poultry and fish production as well as their resistance to disease**.** The use of GM technologies thus comes as solution to the numerous food security challenges facing Africa and the world at large**.** Plant scientist, backed by results of modern comprehensive profiling of crop composition, point out that crops modified using GM techniques are less likely to have unintended changes than are conventionally bred crops**.** The introduction of genetically modified food into our ecosystem have the potential to disrupt all works of life from microbes and bacteria, to the well being and health of humans, to the extinction of endangered species to potentially ending world hunger**.** Extensive public awareness campaigns are required to address the concerns consumers have about the new technology and to highlight biosafety measures and the benefit of genetically modified crops.

Key words: GM crops, engineering, Food security, Nigeria.

INTRODUCTION

Genetic modification, also interchangeably known as genetic engineering or gene-splicing is a set of technologies that alter the genetic makeup of living organisms, such as animals, plants or bacteria (Anno, 2008a). It involves the isolation, manipulation and re-introduction of DNA into cells. These techniques in genetics are generally known as recombinant DNA technology, which is the ability to combine DNA from multiple sources into a single molecule in a test tube (Anno, 2008a).

Genetically modified (GM) foods are thus food items that have had their DNA changed through genetic engineering (Halford, 2003). The most common genetically modified organisms are crop plants. However, the technology has been applied to nearly all works

of life including pets that glow under UV light to goats which can produce spider silk (Mchughen, 2000).
The first commercially grown genetically modified whole food crops was the tomato (called flavr savr), which was made more resistant to rotting by Californian Company, Calgene (Martineau, 2001). Since then, several genetically modified crops have been introduced into the market.
Essentially, the aim of genetic modification is to introduce new physical or physiological attributes that through conventional breeding would not be possible (Beth, 2007). According to Aerni (2005), the introduction of genetically modified foods into our ecosystem have the potential to disrupt all works of life from microbes and bacteria, to the well-being and health of humans, to the extinctions of endangered species to potentially ending world hunger.
In African, the use of GMO technology and its products is still in its infancy (Odame et al., 2003). South African is the only African country that is commercially producing GM crops (Apps, 2005). However, Egypt is approaching commercialization of four GM crops: Potatoes, squash, yellow and white maize and cotton (Mansour, 2005). Apps (2005) report that in South Africa, under the genetically modified organisms Act of 1997, three transgenic crops-insect or herbicide resistant cotton, maize and Soybeans have been approved for commercialization.
The productivity of most African farms is limited by crop pests and diseases (Prakash, 2005). African cassava farmers typically loose 60% of their crops on mosaic virus. Sweet potato yields in many African nations are low. In some cases loosing up to 80% of expected yield on sweet potato weevil and the feathery mottle virus (SPFMV) (Apps, 2005).Vitamin information center (1999) reports that of the 800 million people who live in Africa, nearly 200million are chronically undernourished and some 40 million people mostly children are severely underweight. Over 50million people suffer from vitamin A deficiency while 65% of women of childbearing age are anemic. GMO food offers African an opportunity to increase food security and address agricultural production constraints (Odame *et al*., 2003). Therefore modern biotechnology could be an important tool for sustainable development in Africa and could benefit most of our resource poor farmers (Prakash, 2005).
According to Ngandwe (2005), most southern and Eastern African Countries, Zambia in particularly have regularly placed embargo on the importation of GMO food into their countries. They argue that the developed nations, plans to turn their countries into a dumping ground of their surplus agricultural products. They also claim that there is an associated health risk involved with the consumption of GMO food (Anno, 2008b).
Nigeria is yet to record tremendous success in the commercialization of GM crops (Ekpiwhre, 2008). It is either that policy makers in Nigeria do not only understand what the technology can do, or has done elsewhere, but also to establish what opportunities it presents to Nigerian and African's in general (Daily times, 15 July 2008).
The development and use of genetically modified crops which are more nutrient dense, high yielding, pest resistant, disease resistant, herbicide tolerant, drought tolerant etc may contribute to the alteration of hunger, improved environmental conditions and increased economic benefits (Prakash, 2005).

This report therefore, focuses on the idea to enhance research in GM crops. Adequately funded research and development of GM crops will ensure food security for Nigerians and Africa at large and reduce hunger to its barest minimum.

Origin of GM food/emergence of GM crops into Africa

The first genetically modified food crop was a tomato created by the company Calgene, in California, Called the Flavrsavr (Martineau, 2001). The enhanced tomato was made more resistant to rotting. Engineers were able to add an antisense gene which interferes with the production of the enzyme polygacturonase. (Martineau, 2001). After Calgene submitted Flavrsavr to the food and drug Administration for testing, which determined that it was indeed a tomato and did not pose any health hazard, the company was allowed to release the tomato to consumers in 1994 (Anno 2008a). Consumers were able to buy it at two to five times the price of standard tomatoes. A year later, Mosanto, a leading multinational agricultural biotechnology corporation bought Calgene (Anno 2008b).

Mosanto first introduced GM crops and GM crop plantings in Africa (Anno 2008b). South Africa is the only African country that first embraced this technology (Anno 2008b). In 1999, only 2% of corn planted in South Africa had biotech traits in it (Anno 2008b). This number rose to 60% in 2007. SciDev news (2008) reports that Mosanto South Africa is celebrating 10 years of commercial biotechnology crops in South Africa. During this time, biotechnology use has dramatically increased. The SciDev news (2008) also reports that South Africa, Egypt, Burkinafaso, Kenya are African countries that permit genetically modified farming.

According to Apps (2005), a handful of other African countries including Nigeria and Tanzania are looking at creating a new law to allow planting of GMO crops. The reverse is the case in many other African countries where there is ban and strict control of importations of GMO crops.

In Nigeria, the 1ITA has developed parasite resistant maize (Ngandwe, 2005). This varieties tolerate heavy striga infestation without suffering crop losses. Ngandwe (2005) also reports that there is a wide acceptance of this GM crops in several Nigerian state.

Other examples of genetically modified crops have included cantalopes, herbicide resistant soybeans and sugarbeets, and pest resistant corn and cotton (Anno 2008a).

However, not all of these products are available in grocery stores yet. Nonetheless, the prevalence of GM foods in vegetable oil or breakfast cereals, most likely contain some percentage of genetically modified ingredients because raw ingredients have been pooled from different sources into one processing unit.

Fig 1: Worldwide cultivation of the four main commercial GM crops in 2002 in million hectare .

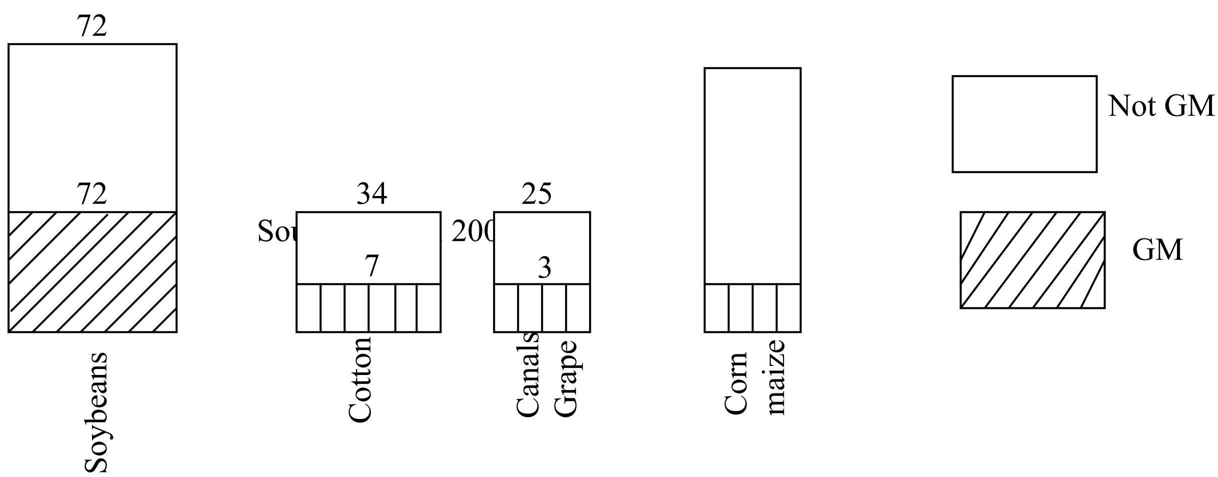


Fig 1 displays the ratio between GM and Non GM crops of the four major products: soybeans, cotton, canola and corn. The figure above shows that GM crop and crop plantings accounts for a little proportion of crop plantings. Of the four major GM crop soybean is the most cultivated. The proportion of GM corn planted is still at its lowest ebb. According to SciDev news (2008), it is believed that in the near future, GM crop planting will supersede non-GM crop planting.

Franken Food

Opponents of genetically modified food often refer to genetically modified foods as "FRANKENFOOD" after the monster in Mary Shelly's novel Frankenster, for whom the book is named, in response to the decision of the FDA to allow the marketing of genetically modified food (Fedoroff et al., 2003). The term is also used to voice the fear that the effects of GM crops are not fully understood and have not been accurately accessed. These effects could be potentially harmful not only to humans but also cause several disturbances in the balance of our ecosystem (Stanley *et al*., 1999).

Arpad (1998) suggested that a few strains of genetically modified potatoes may actually be toxic to laboratory rats. He claims that his experiment showed that rats fed on potatoes which has been genetically engineered to express a lectin suffered serious damage in their immune systems and had stunted growth. The lectin is also toxic to insects and nematodes and supposedly toxic to mammals (Stanley et al., 1999). Arpad's experiments were sent for by the Royal British society and reviewed by six independent experts and regarded that his data was not adequately enough to support the claims he had for a number of reasons. Subsequently, Arpad sent his result to 24 independent reviewers, who disagreed with the conclusions (Witcombe *et al*., 2004). Although the results of Arpads experiment are still largely contested what followed was a European backlash of genetically modified foods (Stanley *et al*., 1999). Today there are strict guidelines and regulation for GM foods in the DNA bar codes (Anno 2008a). Recently conducted surveys still suggested that the public has a negative opinion of GM foods (Anno 2008a). In fact, third world countries in Africa have even rejected international food aid that have any trace of genetic modification (CL, 2005).

Table 1 explains the properties of GM crops currently in Africa and the company commercializing the GM products. SciDev news (2008) reports that south Africa is the leading GM crop producing country in the continent. Egypt is next to South Africa. Burkina Faso and Kenya are major entrant that have started GM crop productions in their Countries (Anno 2008b). In the nearest future, African countries will embrace this technology to help solve her food deficit problems (Scoones, 2005).

Table I: GM crops currently in existence in Africa (Anno 2009a)

Food	Properties of the genetically modified variety	Trade Name	Company	Modification
Soybeans	Resistance to herbicide. Resistance to certain pesticides tolerating crop spray the ways a	Roundup Ready	Mosanto	Herbicide resistant gene taken from bacteria inserted into soybean

	farmer can use			
Corn	Amount of pesticides which would normally kill the parasites without harming the plant	Roundup Ready	Mosanto	New gene added/ transferred into plant genome
Rape seed (Canola)	Bt			New gene added/ transferred into plant genome
Sugar beet	Certain pesticides (tolerating crop)	Round up ready		New gene added/ transferred into plant genome
Cotton	Pest resistant cotton varieties		Mosanto Syngenta	New gene/added transferred into plant genome
Sweet corn	Produces its own insecticides (a toxin to insects, Bt corn so insect attacks are less likely)			Insect killing gene added to the plant. The gene comes from the bacteria Bacillus thuringensis

Global area of biotech crops

Fig 2: Global area of biotech crop planting spanning from 1995-2004

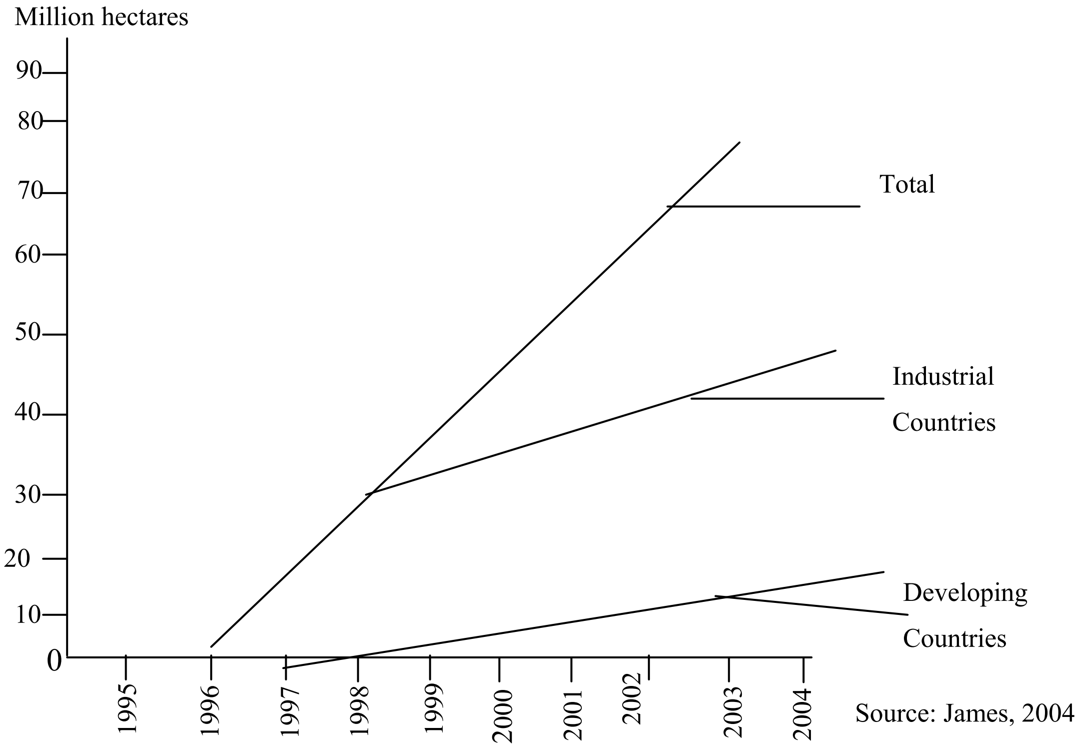


Fig 2: global plantings of biotech crop spanning from 1995 to 2004. GM crops accounts for only 4 percent of global cultivation (James, 2004). In 2004, global plantings of GM

crops jumped by 20 percent. James (2004) also report that soybeans accounted for 60 percent of all GM crops; maize for 23 percent; and cotton for 11 percent. According to James (2004), in the near future, GM maize is projected to have the higher growth rate as more beneficial traits become available and is approved.
In 2004, there were 8.25million farmer involved in GM crop production in 17 countries (Anno 2008b). Although 90% of these farmers were from developing countries only one of these countries, South Africa, was in Africa.
In 1999, only 2% of corn planted in South Africa had biotech trait in it (Anno 2008b). This number rose to 60% in 2007. Mosanto is currently conducting field test in other African countries such as Zimbabwe, Kenya and Burkinafaso and will be planting yield–yard maize in Egypt for the first time this year (SiDev news, 2008). Since the technology was developed 12 years ago in the US, 23 countries have adopted biotechnology and over 12 million farmers plant using this technology, despite the fact that many of these farmer come from poorer developing nations (Anno 2008b). SciDev news (2008) reports that South Africa will produce 11 million tons of food from **2.7** million hectares. Ten years ago South Africa produced maize of 5 million hectares (SciDev news, 2008). So with biotechnologies in place, one can assure that it would not give us less than 60 million tons of maize (Anno 2008b).

The technique of genetic modification

The first step in developing a transgenic plant is to identify a trait in one type of organism that would make a useful characteristic if transferred to the experimental plant (Maliga, 2001). The components of an experiment to create a transgenic plant are the gene of interest, a piece of "vector" DNA that delivers the gene of interest, and a recipient plant cell (Fletcher, 2001). Donor genes are often derived from bacteria and are chosen because they are expected to confer a useful character such as resistance to a pest or pesticide (Hilemann, 2001).
To begin, the donor DNA and vector DNA are cut with the same restriction enzyme (Fletcher 2001). This creates hanging ends that are the same sequence on both of the DNA molecules. According to Maliga (2001) some of the pieces of donor DNA are then joined with vector DNA, forming a recombinant DNA molecule. The vector then introduces the donor DNA into the recipient plant cell, and a new plant is grown (Maliga, 2001).
Hileman (2001) reports that for Dicots, a naturally occurring ring of DNA called a Ti Plasmid is the commonly used vector. He is if the view that for Monocots, T1 plasmids do not work as gene vector. Instead, donor DNA is usually delivered as part of a disabled virus or sent in with a jolt of electricity or with a "gene gun" ie particle bombardment (Potrykus, 2001).
Transgenesis in plant is technically challenging because the transgenic must penetrate the tough cell wall, which are not present in animal cell (Maliga, 2002). Maliga (2001) also reports that instead of modifying plant genes in the nucleus, a method called transplastomics alters genes in the chloroplast, which is a type of organelle called a plastid. Chloroplast houses the biochemical reaction of photosynthesis (Dutta, 2004). Transplastomics can give high yield of protein products compared to one nucleus (Maliga, 2001). According to Fletcher (2001) another advantage is that altered chloroplast genes are not released in pollen, and therefore cannot fertilize unaltered plants. However, it is difficult to deliver genes into chloroplast and expression of the trait is usually limited to leaves (Fletcher, 2001). This is obliviously not very helpful in all plants whose fruits or tubers are eaten. Hilemann (2001) also report that the technique

may be more valuable for introducing resistances than enhancing food qualities. Someday, transplastomic may be used to create medicinal fruit's or edible vacuums (Maliga, 2001).

GM beyond the laboratory

After genetic modification, the valuable trait must be bred into an agricultural variety (Potrykus, 2001). Consider "golden rice" a grain that was given genes from daffodils and a bacterium to confer on it the ability to manufacture carotene, a precursor to vitamin A. Potrykus (2001) also reports that the first golden rice plant was created solely to show that the manipulation worked and the modification of an entire biochemical pathway took a decade. The plant varieties were not edible, and the production of beta carotene was low.

In early 2002, however, researchers at the international Rice research institute in the Philippines began using conventional breeding to transfer the ability to produce beta carotene from the variable golden rice into edible varieties (Anno 2008a). Kenyan Agricultural Research institute (KARI) also employed the conventional breeding method in producing Bt cotton (Anno 2009b). SciDev net news (2008) reports that researchers in South Africa had in 2005 employed the same method in producing Bt maize.

GM crop research in Africa

Globally, GM research and development is led by five large multinational life Science companies independently or in collaboration with the Advanced Research institutes (ARIS) in the industrial countries (James, 2004). These companies include Mosanto, Syngenta, Aventis, Crop Science and Dupont. Table 2 list the life science companies and their countries of origin

Table 2: Top five multinational life science companies present in Africa, their countries of origin and research objective.

Life science companies/agro chemical company	Countries of origin	African countries present	Research objective
Mosanto	USA	South Africa, Egypt, Kenya, Burkinafaso, Zimbabwe	
Dupont	USA	South African	
Syngenta	USA	Burkinafaso, Mali Guinea Nigeria, Ghana Kenya	Geared towards producin g food security in the world
Aventis	Argentina, Brazil	Malawi	

		Benin, Cameroon South Africa	
Crop Science	Canada, USA	Ghana, Algeria, Egypt	Geared towards ensuring food security in the world

Source: Anno 2008 b

The five major life source companies are all geared towards ensuring food security in the word (Anno 2008 b).
An increasing number of African countries have GM research and development capacity (Anno 2008). South Africa, Zimbabwe, Kenya, Nigeria, Mali, Egypt and Uganda are widely acknowledged as being the lead countries (Anno 2008b). According to Glover (2003) as many as 24 other African countries have some GM research and development capacity. These countries includes Benin, Burkinafaso, Cameroon, Egypt, Ghana, Kenya, Malawi, Mali, Mauritius, Morocco, Namibia, Niger, Nigeria, Senegal, South Africa, Tanzania, Tunisia, Uganda, Zambia and Zimbabwe. Glover (2003) also reports that nine countries Benin, Burkinafaso, Egypt, Kenya, Morocco, Senegal, Tanzania, Zambia, and Zimbabwe are known to have conducted field trials. Supporting legislation and policy to regulate research and commercialization processes have not kept pace with this development (Anno 2008b).
In Africa, the main GM crops of research and commercial interest are sweet potato, maize cotton, Soybeans, pigeon peas, bananas and Tobacco (Glover 2003). Much of this research is based on public private partnership as shown for selected countries in table 3.

Table 3 gm research based on public private partnership of some selected countries in Africa

Country and Project name	**Partners and Funders**	**Research Objective**	**Additional Information**
KENYA Insect Resistant maize for Africa	Kenyan Agricultural Research institute (KARI) IN collaboration with the international maize and wheat improvement center (CIMMYT) funded by syngenta foundation for sustainable Agriculture	Bt Maize resistant to the stem borer	Open field trials started in may 2005. Government authorities destroyed crops in August 2005 due to spraying of restricted chemicals
Kenya	Kari, Mosanto, International service for the Acquisition of Agriculture Application funded by USAID and Mosanto	Field test of two Bt cotton varieties	

EGYPT	Mosanto and Egypt Agricultural Genetic Engineering Research Institute (AGERI) currently collaborating in field trials of Bt cotton. Laboratory work is been due on 22 GM crops; Potatoes, tomatoes, corn, faba bean, wheat, cucurbit and cotton. Field trials are being conducted for insect-Resistant and virus resistant cucurbits. GM crops will be available soon on the commercial level	Multiple crops insect resistant	Commercial introduce take place as early as 2006
Burkinafaso	In 2003, Mosanto, Syngenta and Burkinafaso Institut National DeL Environment et la Recherche Agronomique (INERA)	Field test of two Bt cottons Variety	Researches taken place without the involvement or consent of the national biosafety committee which is tasked with developing a national regulatory regime for GMO'S

Sources: Odame *et al*., 2003; Glover 2003: Mausour 2005.

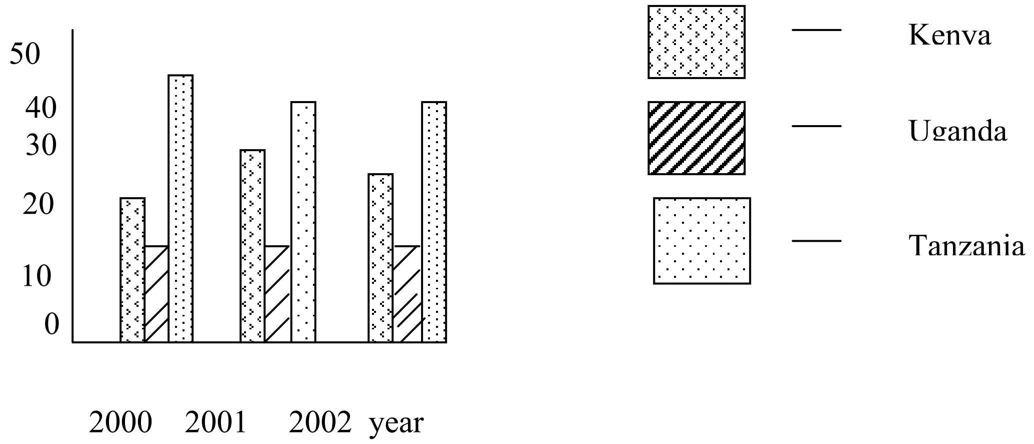
Research co-operation between developing countries and institutions or companies based in the developed world has been important in promoting transgenic research in Africa (Glover 2003). For example, the Swiss federal institute of technology (SFIT) in Zurich plans to collaborate with researchers in Kenya, Nigeria, UK and the USA on the African cassava mosaic virus (Anno 2008b). The virus is transmitted to cassava by white flies when they feed on the plant (Anno 2008b). SciDev net news (2008) repots that this research of special interest (Cassava mosaic virus research) is nearing completion and will be released to farmers soonest.
The Nigerian laboratory of the international institute for Tropical agricultural (IITA) has successfully developed a parasite resistant maize (Ngadwe, 2005). This varieties tolerate heavy striga infestations without suffering crop losses. The varieties known as sammaz 15 and 16 contain genes that diminish the growth of parasitic flowering plants such as striga which attaches to the maize root. SciDev net news (2009) reports that they dramatically cut maize losses from the root-infecting striga or witch weed, during 2 years of trial cultivation by farmers in Borno state in Northern Nigeria. IITA has begun distributing the new parasitic resistant maize seeds since December 2008 (Anno 2009b).

Other Nigerian research institute such the national research institute for root and tuber crops are carrying out researches on GM crops (Anno 2009b). Of pre-eminence is the drive to produce genetically modified yam. It is believed that in the near future several Nigerian crops would have been modified to produce better yield and improved agricultural crops (Anno 2008b).

FOOD SECURITY AND AGRICULTURAL PRODUCTION IN AFRICA

In the last ten years, progress in the drive to reduce hunger has been slow and has varied around the world (FAO, 2005). According to FAO ? (2005) report, the number of hungry people in sub-Saharan Africa has in fact increased by 20% since 1990. A cursory look at fig 3 indicates the proportion of hungry persons in selected African country.

Fig 3: Percentage of hungry people leaving in Kenya, Uganda and Tanzania between 2000-2002.



Source: FAO 2006

In the period 2000-2002 the proportion of undernourished people in the total population of Kenya was 33%, in Uganda 19% and in the united republic of Tanzania 44%. FAO (2005) reports also states that the number of underweight children has also increased in central, western and Eastern African compared to an overall decline in other developing region such as Asia, South America and North Africa. This is illustrated in fig 3.

From fig 4 above it can be deduced that the number of underweight children in Eastern, Western and Southern Africa soar above 50 million, while compared to less than 50 thousand in the developed world. Asia, North Africa and South Africa are almost cutting down the level of food shortage in their countries (FAO, 2006).

Africa therefore faces a fundamental food security challenge (UNEP, 2008). Arguably the most sustainable choice for agricultural development and food security is therefore to increase total farm productivity insitu in the developing countries that are most in need of greater food supplies (FAO, 2005). According to UNEP (2008) attention must focus on the extent to which farmers can improve food production and raise income with low cost, locally available technologies and imports. The use of GM technologies thus comes as solution to the numerous food security challenges facing Africa and the world at large (Anno 2008b).

Fig 4: Comparison of underweight (undernourished) children in different parts of the world

Future Developments

Future envisaged applications of GMOs are diverse and include drugs in food, bananas that produce human vaccines against infectious diseases such as hepatitis (Kumar et al, 2005), metabolically engineered fish that mature more quickly, frit and nut trees that yield years earlier and plants that produce new plastics with unique properties (Van et al., 2008). While their practicality or efficacy in commercial production has yet to be fully tested, the next decade many see exponential increase in GM product development as researchers gain increasing access to genomic resources that are applicable to organisms beyond the scope of individual projects (Armo 2008a). Safety testing of these products will also at the same time be necessary to ensure that the preceded benefits will indeed outweigh the perceived and hidden costs of developments (CL, 2005). Plant scientist, backed by results of modern comprehensive profiling of crop composition, point out that crops modified using GM techniques are less likely to have unintended changes than are conventionally bred crops (Sirpa *et al*., 2006; catchpole et al., 2005).

Benefits of GM foods

Genetic modification technique allow for novel traits to be introduced into animals, crops and micro-organisms (Anno 2009a). These techniques can be used to improve livestock, poultry and fish production as well as their resistance to disease (Young, 2004). Young 2004 reports that genetic modification is being used in the forest sector to create pest resistance, herbicide tolerance and wood quality traits. According to Yamin (2003), crops can be genetically modified to improve appearance, taste, nutritional quality, drought tolerance, insect and disease resistance. GM crop can thus often help up as the solution to yield deficit.
The introduction of genetically modified food into our ecosystem have the potential to disrupt all works of life from microbes and bacteria, to the well being and health of

humans, to the extinction of endangered species to potentially ending world hunger (UNEP, 2002).

What GM crops hold for Africa

Genetic modification (engineering) of crops is an extension of the age-old practice of cross breeding and selection to develop new crop varieties (Kappeli and Auberson 1998). With traditional breeding methods, thousands of traits from two crops are combined. Using genetic engineering only the desired characteristics are added to a plant (Tester, 1999) and this technique holds a lot for Africa (Anno 2009a). Some of the benefits, Africa stands to derive include:

Increased Food Production

Genetically modified crops can end world hunger. The biotechnology of gene splicing can increase the yield of such crops as rice which feeds million in Africa and Asia and cassava a tuber commonly eaten in Africa by producing crops which are pest resistant and herbicide tolerant, thereby reducing losses to insects and pests (Leplaideur, 2000).
In addition, GM crops can increase food production especially in Africa by making new crop land available by producing new variety of crops able to tolerate high salinity levels in soil, high acidity, drought and cold, thereby making areas with poor soil that other otherwise would not be used for agriculture (Farming) useful (Anno 2009a)

Improved nutritional and health benefits

The biotechnology of gene splicing allows for the opportunity of creating crops that will produce food that is more nutrient dense (Anno 2009a). FAO (2005) reports underscores the importance of nutrient dense food as it tends to reduce the large proportion of undernourished people in Africa. Some examples of GM crops with improved nutritional and health benefits are listed in Table 4.

Table 4: GM crops with improved nutritional and health benefits.

GM crops	Nutritional/health benefit
Golden Rice	Prevents vitamin A deficiency
Transgenic Rice	Improve oral rehydration for treatment of diarrhea
Maize	Provides better quality protein for man and animal
Lettuce	Lower cholesterol level

Source: (Anno 2009a)

Golden rice which contains beta carotene a source of vitamin A and iron which may one day help prevent vitamin A deficiency which causes blindness in over 10 million children in Africa and around the world (Prakash, 2005).
Transgenic rice" developed by Calgene to improve oral rehydration therapy for diarrhea. In sub Saharan Africa, Asia and parts of Latin America, diarrhea is the number two infection killer of children under the age of five accounting for more than two million deaths a year (Anno 2009a).
Recently in 2005, six trials in Peruvian hospital have demonstrated that specialized milk proteins transgenic rice and lysozymes contained in transgenic rice, improved the effectiveness of oral dehydration solution used to treat diarrhea (Anno 2009a).

Maize with enhanced level of the essential nutrients, lysine which provides better quality protein for animal feeds and human consumption (Kappeli and Auberson 1998).
Lettuce that help lower Cholesterol level in the body (Anno 2008b)

Improved Environmental Condition

Pest resistant and herbicide tolerant GM crops reduce the need for spraying corps with unhealthy chemicals that can enter into the food supply (Okigbo and Ogbnnaya 2006). According to FAO (2006) "with the high level of illiteracy and few laboratories in place to detect the effect of chemical on crops, African countries is benign to suffering from severe infection as a result of this chemicals.
GM crop, thus contribute to reduced green house, gas emission and pesticide load in the environment due to reduced use of chemicals (Anno 2009a). GM crops also help in protecting the environment by making it possible for farmers to do less ploughing and weeding, the practice also known as conservative tilling cuts down soil erosion and improve water quality by reducing runoff into rivers and streams (FAO 2005; Conway, 2000). This is most beneficial to African countries where mechanized faming is not practiced.

Improved Economic Benefits

In 2005, GM crops were grown by 8.2 million farmers in 21 countries. The twenty-one countries and the crops grown are listed in table 5.

Table 5: Twenty one GM crop countries

Rank	**Country**	**Area (million hectares**	**GM crops**
1	USA	49.8	Soybean, maize, cotton, canola, squash, pawpaw
2	Argentina	17.1	Soybean, maize, cotton
3	Brazil	9.4	Soybean
4	Canada	5.8	Canada, maize, soybean
5	China	3.3	Cotton
6	Paraguay	1.8	Soybean
7	India	1.3	Cotton
8	South Africa	0.5	Maize, soybean, cotton
9	Uruguay	0.3	Soybean, maize
10	Australia	0.3	Cotton
11	Mexico	0.1	Cotton. Soybean
12	Romania	0.1	Soybean
13	Philippians	0.1	Maize
14	Spain	0.1	Maize
15	Columbia	< 0.1	Cotton
16	Iran	< 0.1	Rice
17	Honduras	< 0.1	Maize
18	Portugal	< 0.1	Maize
19	Germany	< 0.1	Maize
20	France	< 0.1	Maize
21	Czech republic	< 0.1	Maize

Source: James (2005)

Of the GM crops grown, 90% of the beneficiary farmers were resource poor farmers from developing counties whose increased income from GM crops contributes to the alleviation of their poverty (James, 2005). Also notable is the global value of this GM crops.

Table 6: global value of GM crop market in billion dollars

GM crop	value	Percentage of global
Soybean	$ 2.42	46%
Maize	$ 1.90	36%
Cotton	$ 0.72	14%
Canola	$ 0.21	4%
Total	$ 5.25	100%

Source: James (2005)

According to table 6 the global value of GM crops was $5.25 billion in 2005. The accumulated global value for the ten year period since 1996 is estimated at $29.3 billion (James 2005), Africa's over dependence on food aid will be greatly reduced with her adoption of GM crops and crop planting (Prakash, 2005). Prakash (2005) also noted that this will in turn increase their export level, thereby generating income and alleviating poverty.

Improvement in fruit storage

One of the problems with fruits is that when they are left on the plant for too long they get marshy during stripping and storage. Uno *et al.* (2001) reports that to overcome this problem, fruits are picked and shipped while they are still immature. They are later ripened by exposure to the hormone ethylene. Unfortunately such ripened fruits often have little flavor (Uno *et al.,* 2001). Moffat (1998) reports that genetic engineering was used to solve the problem of rot in tomato. Botanist in Calgene company introduced an altered gene that shows the enzyme system that affects the mushiness of the tomato fruit (Anno 2009a). Such genetically engineered tomatoes that are left to ripen on the parent plant maintain their firmness and flavor during storage (Moffat, 1998).
This is in fact helpful to Africa as it shall help to increase the profit of farmers that make less gain as a result of poor storage facilities (Anno 2008b).

Herbicide tolerance/resistance

According to Uno *et al.* (2001) plants are killed by glyphosphate (roundup) a herbicide that inhibits an enzyme called Epsp synthetase that is required for making aromatic amino acids. He opined that when plants cannot make aromatic amino acids, their metabolism stops and they die.
Glyphosphate resistant crops have been made by inserting extra copies of the EPSP synthetase genes into them (Nelson and Cox 2000). These crops contain enough enzymes to overcome inhibition by glyphosphate. Ideally crops that resist ghphosphate or other herbicides do no need to be weeded, thereby treating a field with the herbicide that kills the weed but does not affect the genetically engineered crop (Moffat, 1998). These herbicides are soil friendly and less toxic thereby eliminating residue carryover problems and reduce negative environmental problems (FAO 2004). This holds a lot for African farmers.

Insect/pest resistance

According to Uno *et al* (2001) insects cause a lot of damage to crops in tropical Africa thereby reducing their productivity and yield. Crops containing Bt (*Bacillus thuringiensis*) gene have been produced which contains a toxin that kills insect that feed on them but is harmless to humans and to other species which are not considered as insect pest (Uno *et al*., 2001)

Table 7: BT crops currently in the market

Crops	**Insect controlled**
Corn	For the control of European corn borer, corn ear worm, south western corn borer, corn root worm
Cotton	For the control of bollworm
Tobacco	For the control of tobacco budworm

(**Source:** Uno *et al.,* 2001)

FAO reports of 2004 stated that the use of insect/pest resistant crops (Bt crops) have dramatically reduced the amount of chemical pesticide applied to crops land and has also improved the health condition of farmers by reducing their exposure to these chemicals which otherwise they would have sprayed on their farms.

Disease resistance

Botanist have discovered a variety of genes involved in disease resistance by plants (Uno et al., 2001). For instance, the gene of the protein coat of tobacco mosaic virus (TMV) has been transferred to tobacco and the plant developed resistance to the virus (Uno et al., 2001). There is presently research co-operation between Nigeria and Swiss federal institute of technology (SFIT) to produce cassava that is resistant to the mosaic virus (Anno 2009b). This cassava when fully developed will be of immense benefit to Nigerians and African farmers in general (Anno 2009b).

Approaches to gm food and food aid in Africa

Drought, inadequate water resources and poor soils, along with other economic and social pressures, have made food shortage a problem in many parts of Africa (Mansour, 2005). This has necessitated for a food aid Programme in Africa (Scidev net news, 2008). According to Apps (2005), GM crops have been offered as food aid from the year 2002. In southern Africa, several countries have expressed concern about the use of GM crops as food aid, given the lack of clarity about their potential impacts. Apps (2005) also report that in the drought of 2002-03, several countries opted to reject GM food aid. In making their decision, countries consisted not only the immediate issue of food shortage and the overall implications of GM crops for human and environment or health but also future direction in agriculture, the implications of private sector led research, livelihood and development options, ethical issues and right concerns. Similarly, public concerns are raised about the relationship between GM crops, and sustainable agriculture participatory Ecological land use management (PELUM- Tanzania, PELUM-Kenya, PELUM-Zimbawe), Biowatch South Africa and national consumers council have all been key players (Anno 2008b; Apps, 2005).

Table 8 Approaches to gm food and food aid in selected African countries

Countries	GM status	Approaches to GM food
Angola	Nil	Restricts the importation of GM food and food aid
Zambia	Nil	Refuses GM food aid
Zimbabwe	Present	Accepts GM food aid but with condition
Mozambique	Nil	Restricts importation. There is ban of GM food
Malawi	Present	Accepts GM food and food aid
Lesotho	Present	Accepts GM food and food aid importation but with conditions
Sudan	Nil	Restricts the importation of GM food
Nigeria	Present	No form of ban of GM food and food aid

Sources: Anno 2008b, Ngandwe 2005

Mozambique raised concerns about accepting GM maize on biosafety and human health grounds and opted to ban its importation (Anno 2008b). Zambia refused to accept GM food aid in any form (Ngandwe, 2005). Zimbabwe, Malawi and Mozambique refused to accept GM food aid unless it was milled, thus being seen as a precaution to avoid any germination of whole grains and to limit impacts on biodiversity (Anno 2008b). Ngandwe (2005) reports that Swaziland and Lesotho authorised the distributions of non-milled GM food but not before it warned the public that the grain should be used strictly for consumption and not for cultivation and in 2004, Angola and Sudan introduced restriction, on GM food aid (Ngandwe, 2005).

Global anti GM food campaigns have influenced public attitudes to GM foods in Africa (Anno 2008b). Consumers international (CI) a worldwide federation of consumer organization with 38 member organization in about 22 African countries, has played an importation role in shaping the debate on GM food (CI, 2005). It advocate a legal regime in which all GM foods are subject to rigorous, independent safety testing, labeling and traceability requirements and in which producers are held liable for environmental or health damage which their products may cause. There is a growing acceptance of this approach globally [CI, 2OO5].

Drivers and constraints

As elsewhere, globalization, trade liberalization and deregulation, research and development lie at the heart of the push of GM technologies into Africa (Anno 2008b). Yamin (2003) is of the view that Africa's receptiveness is shaped by concerns about food insecurity, growing poverty and inadequate nutrition as well as declining public agricultural research budgets and capacity.

Decaling public sector African agricultural research combined with the privatization of agricultural research, has led to a focus on providing
hi-tech solutions, including transgenic over other agricultural option (Young, 2004). Globally driven agricultural research and technology development, which defines Africa's food security problems as being primarily about yield, possess the "quick fix" of GM crops and is particularly attractive (Anno 2008b). The multiple stressors that are driving food insecurity, including the interplay between inadequate access to water, poor soil fertility, climate change, inadequate infrastructures, weak markets, poverty,

HIV/AIDS and civil war are inadequately taken into account in developing solutions (Scoones, 2005).

Although human development, food security and environmental health issues are often the focus of the marketing strategies of the main research and development companies it is unlikely that such altruistic consumers are driving their investment (Yamin, 2003). Odame et al (2003) reports that Africa and the developing world is an important potential market as consumer and producer, given that Europe is receptive to GM products and that more than 70% of Africa's people are engaged in agricultural production.

The absence of a supportive policy legal framework is often cited as an inhibiting factor for the development of biotechnology (Anno 2008b). On the one hand, biotechnology companies may be reluctant to invest in costly research without the legal guarantee that they will be able to commercialize their products. Yamin (2003) is of the opinion that supportive legislative framework for research include not only clear rules for risk assessment and commercialization but also intellectual property rights (IPR). Although IPR standards have been developed through the world trade organizations, intellectual property rights (TRIP), domestic IPR legislation in many African countries remain weak (Anno 2008b). Many countries struggle with how to reconcile IPRs with farmers right and other local interests. There are concerns that strong IPRs will entrench global domination of world food production by a few companies and increased dependence on industrious nations. IPR may place restriction on farmers, including on their existing rights to store and exchange seed (Yamin, 2003).

According to Anno (2008b], the lack of adequately inclusive policy processes has contributed to a polarized GM debate. SCIDEV net news (2008) reports that civil society has been increasingly recognized as an important partner in the development of environmental policy, after the United Nations Conference on Environment and Development (UNCED) held in 1992. Civil society organizations, globally and within Africa, have been very active in claiming this space around issues related to genetic modification. A range of concerns has been raised related to the debates around human well being (Yamin 2003).

Another set of concern relating to policy making processes is the growing influence of the scientific and private sector in policy development and how to balance this with public concerns (Mohamed katere, 2003). Issues of public trust accountability and transparency, as well as fairness and consumers rights, underlie much of this. In many areas, public objection to and concerns about GMOs are important constraints to GM research and the commercialization of GM products. Globally these concerns focus on health and environmental implications (Odame et al., 2003).

Debates around Africa and beyond

Many scientists argue that there is more than enough food in Africa and the world and that the hunger crisis is caused by the problems in food distribution and politics, not production, so people should not be offered food that may carry some degree of risk (Lappe *et al.*, 1998).

Activist and many scientist opposed to genetic engineering say that with current recombinant technology there is no way to ensure that genetically modified organisms will remain under control, and the use of this technology outside secure laboratory environments represents multiple unacceptable risk of both farmed and wild ecosystems (Raney and Prahbu, 2008). Proponents of genetic techniques often cite hypothetical

benefits that the technology may have, for example, in the harsh agricultural condition of Africa (Boucher, 1999). They say that with modification, existing crops could possibly be able to thrive under the relatively hostile condition providing much needed food to their people.
According to Boucher (1999), proponents claim that genetically engineered crops, although patented for economic benefit are not significantly different from those modified by nature or humans in the past. They also argue that modified crops are as safe, or even safer, than those created through such time tested methods. There is gene transfer between unicellular eukaryotes and prokaryotes. They argue that animal husbandry, food irradiation and crop are also forms of genetic engineering that use artificial selection instead of modest genetic modification techniques. It is politics they argue, not economics or science that causes their work to be closely investigated, and for different standards to apply to it than those applied to other forms of agricultural technology (Raney and Prahbu, 2007).

CONCLUSION

Ready or not, it in evident that biotechnology offers Africa and the world at large an opportunity to address the food security constraints through the development and use of drought tolerant, pest resistant, herbicide tolerant, disease resistant and high yielding nutrient dense genetically modified crops (Anno 2009a; Prakash 2005).
Although the development and use of GM crops has been criticized by many as being unnatural and posing an inaccessible risk to biodiversity (Anno 2009b), if properly handled and tested before use it could contribute to increased economic benefits and reduction in starvation especially in the third world (Anno 2009b; Prakash 2005).
Other developing countries have seen the advantage of cultivating GM crops, African countries should not be left out. They should emulate South Africa in the cultivation and use of GM crops.

RECOMMENDATIONS

The need for biotechnology in Africa for the development of genetically modified crops is indispensable as it would help in the development of the continent. Therefore; extensive public awareness campaigns are required to address the concerns consumers have about the new technology and to highlight biosafety measures and the benefit of genetically modified crops (Anno 2008a).
All information on biotechnology and biosafety should be clear accurate, holistic and balanced (FAO 2005).
Strong African participation is needed from all stakeholders at international and regional levels to ensure that the needs of African's are met (Leplaideur 2000).
Funding is needed to implement the production of GM crops and its testing; Increased financial commitment from government in this reign should be encouraged (Leplaideur 2000, Anno 2009b). Partnership, collaboration, networking and transparency are needed to maximize the use of available resources (Leplaideur, 2000).
Genetically modified foods and crops should be properly labeled in the market place to enable consumers make their choice (FAO, 2005).

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