African Journal of Biotechnology Vol. 10(77), pp. 17663-17677, 5 December, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.1245
ISSN 1684–5315 ©2011 Academic Journals

Review

Benefits and concerns surrounding the cultivation of genetically modified crops in Africa: The debate

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Accepted 15 July, 2011

Concerns about genetically modified (GM) foods are necessary; however, in Africa concerns are hindering the progress of agricultural practices. Due to lack of education and awareness, it is necessary for African Governments to emphasize the numerous benefits and future prospects of GM food, through education and well grounded evaluation system to improve on the level of acceptance. Thus, the objective of this study was to address the constraints that sub Saharan agricultural sector is faced with and the ability of green biotechnology seeds to significantly counter those issues as well as the various arguments and concerns put forward by critics as to why GM food should not be implemented on African soil.

Key words: Biotechnology, concerns, genetic modified organisms (GMO), food security, benefits, biodiversity, Africa.

INTRODUCTION

The agriculture sector is the largest and most central source of economic income and food security in sub Saharan Africa (SSA) as farming in the sub Sahara African region contributes to three quarters of the regions populations' income and sustenance (Machuka, 2001). Positioned in priority below oxygen and water, food is the third most important life sustaining source with crops being a much more essential source of food in comparison to meats derived from such as poultry, livestock etc. Countries within the sub continents region have long been faced with increasing food insecurity, lack of distribution and lack of higher crop yields due to a myriad of intersecting environmental, economic and social challenges (Messmore et al., 2007). Soil nutrient depletion, increased temperatures, prolong and intense drought conditions due to global climate change, and rampant pest and disease incidents are some of the environmental stressors that have placed considerable strain on agriculture (Drechsel et al., 2001). With an ever increasing population, also placing considerable strain on the region's agricultural sector, Drechsel et al. (2001) further discusses the general unsustainable dynamism between population, agriculture and the natural environment. Thomson (2008) explains that malnutrition continues to increase with the increase in population making it very difficult to maintain adequate food consumption levels.

According to Abah et al. (2010), crop yields have grown slowest in many parts of the developing world, especially in Africa. Traditional methods of agriculture and the methods of the green revolution, the use of fertilizers, pesticides and irrigation, are failing to increase crop yields (Machuka, 2001). This has resulted in the failure to deliver enough food to satisfy the widespread hunger, malnutrition and poverty stemming from the food crisis. Africa's crop production per unit area of land is the lowest in the world. For example the production of sweet potatoes, a staple food is 6 tons per hectare compared to the global average of 14 tons per hectare. China produced 3 times African average (Wambugu, 1999). Asia's green revolution achieved increases in crop productivity that were sufficient to lower the proportion of the population suffering from chronic malnutrition from 40 to 20% while the overall population is more than doubled (Toenniessen et al., 2003). The success of the green revolution in sub Saharan Africa did not match that of Asia because of a lack of a dominant farming system, predominance of rain-fed agriculture as opposed to irrigation and prevalence of soils of poor fertility (Thomson, 2008). Sub Saharan Africa is in need of sustainable agriculture methods of farming on both commercial and subsistent levels. An integrated system of plant and animal production practices that can satisfy the populations food and fiber needs, enhance quality of natural resources and environmental quality, sustain the economic viability of farm operations and finally boost the quality of life for farmers and society as a whole (Abah et al., 2010).

There is growing evidence that genetically modified (GM) crops have the potential to improve world food security and enhance sustainable agriculture (Braun, 2002). Mannion (1995) defined biotechnology as the harnessing of living organisms and/or their components to undertake specific processes and/or generate useful products. Biotechnology encompasses a whole range of research tools that scientists use to understand and manipulate the genetic make-up of organisms for use in agriculture, crops, forestry, livestock and fisheries. Genetically modified crops have the ability to grow faster with development time being reduced from years to months as compared to that of traditional breeding (Stephenson, 2010). Other benefits include increase in crop yields, improvement in breeding insects, pest, disease and weather resistant as well as herbicides tolerant crops. The use of GM plants and animals as bio-factories to yield raw material for industrial uses, drug manufacture as well as recycling and/or the removal of toxic industrial wastes cannot be underrated. Consumers stand to benefit from increase in nutrient value, medicinal properties, taste and aesthetic appeal of the crops (Falk et al., 2002; Uzogara, 2000).

There is no doubt that production of genetically modified organisms (GMOs) in sub Saharan Africa especially within its agricultural sector has the potential to address the many socio-economic and environmental problems (Wambugu, 1999). In the face of encountering malnutrition, biotechnology will make it easier to maintain traditional diets while improving their nutritional values. According to Cook (2000) there are no indications that genetically modified crops are more dangerous than traditionally bred varieties. Parts of West Africa have shown decreases in the prevalence of malnutrition in recent years (InterAcademy Council, 2004). Modern agricultural biotechnology also has the potential to play a large role in preserving declining resources of forests, soil, water and the arable land for present use, and also for the future generations (Bunders and Broerse, 1991). In spite of the attractive benefits, genetically modified crops are usually received with varying emotions worldwide (ASAAF, 2010). Contrasting views have sparked many debates on the topic. Stephenson (2010) stated that the heart of the GMO controversy is whether genetic engineering poses a risk to human health and the environment. Braun (2002) stated that pharmaceuticals and vaccines made by genetic engineering are well accepted all over the world, however, there are many people, particularly in Europe, who are worried that food made by the same new technology, may harm their health or cause damage to the environment. This is despite the growing evidence that genetically modified crops have the potential to improve world food security and the fact that there have not been adverse consequences resulting from their use in the food chain. Many sub Saharan African leaders have been reluctant to approve green biotech due to widely circulated fears and concerns, insufficient knowledge, a shortage of skilled people in the field of biotechnology, poor funding of research, lack of appropriate policies and civil strife (Wambugu, 1999). In 2002, Zambian government refused GM food aid from the United States in the midst of serious famine. The issue was whether the food aid was GM grain and whether there were health, environment and trade concerns (BBC News, 2002; Bodulovic, 2005). Zambia has now established National Biosafety and Biotechnology Strategy Plan to regulate GM crops (Government of Zambia, 2005). Namibia cut off all corn trade with South Africa in 2004 because the latter grew GM crops (Eicher et al., 2006). ASSAF (2010) reported that low Government commitment in Africa to fund development efforts in the area of GM is a fact. Thus, the purpose of this study was to highlight the constraints that sub Saharan agricultural sector is faced with and the ability of green biotechnology seeds to significantly counter those issues. Additionally, various arguments and concerns put forward by critics as to why GM should not be implemented on African soil will be presented.

POVERTY AND MALNUTRITION

Extensive literatures, reports, articles and statistics have and continue to emphasize the impoverished conditions and widespread malnutrition that is evident across the face of the African continent (Collins et al., 2006; Sanchez, 2002; Zere and Mantyre, 2003). Eicher et al. (2006) describes Africa as a hungry continent and the poorest most insecure food region in the world. Thomson (2008) portrayed it as a place where, because of famine, disease and growing populations, almost 200 million people are undernourished and 33 million children go to sleep malnourished and hungry every night. In the past 20 years, the number of Africans who live below the global poverty line ($1 per day) has increased by more than 50%, and more than one-third of the population of the continent continues to suffer from hunger (Kates and Dasgupta, 2007). Ejeta (2010) further remarked that sub-Saharan Africa remains the only region in the world where hunger and poverty prevail. Henley et al. (2010) also discussed the increase in child malnutrition in the region. Figure 1 gives a clear view on this. Recently, the African food crisis has been aggravated by increasing world market prices and the global financial crisis, with both affecting the region's ability to rely on food imports and thus compounding riots on food prices which will lead

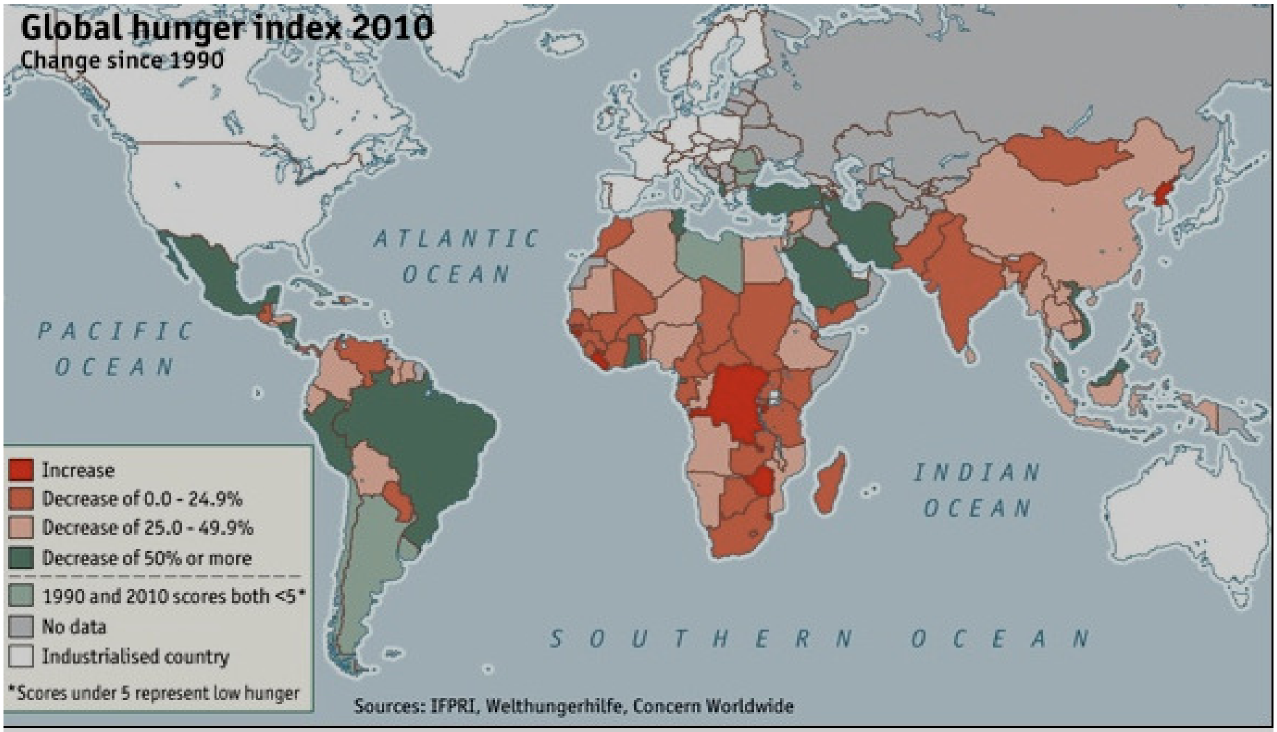

Figure 1. Undernourished countries in the world (IFPRI, 2010).

to social unrest (Holmen and Hyden, 2010).

The increase in population growth rates on the continent has furthered the increase of malnutrition as the numbers of mouths to feed are also increasing (Thomson, 2008). The relationship between population growth in sub Saharan Africa is becoming increasingly inversely proportional to the availability of food supply on the continent. It has been estimated that sub Saharan Africa which includes many of the poorest countries in the world, is likely to more than double in population size by the year 2050 (Goblier, 1997). According to Drechsel et al. (2001) projections to 2010 suggested that the region failed to meet the production of food calories per capita to an average of 2730 per day.

BIOTIC AND ABIOTIC FACTORS CONTRIBUTING TO SSA'S AGRICULTURE STAGNATION

Agricultural production is faced with multifaceted challenges from global climate change (Long et al., 2006). Carbon dioxide (CO_2) and other greenhouse gases are accumulating in the atmosphere at unprecedented rates (Le Quéré et al., 2009; Shindell et al., 2009) leading to global warming and extended drought periods. Low rainfall is causing arable land in Africa to decrease. Pest increases, insufficient funds for adopting modern techniques of dealing with crop pests and viruses also constitute problems which continue to undermine food security in many parts of Africa (Abah et al., 2010). Genetically engineering tolerance to weed killers in crops allows farmers to spray their fields to eradicate pests with herbicides without damaging their crops. Herbicide-tolerant soybean, corn and cotton are the most successful GM crops in the world (Asante, 2008).

One of the greatest challenges today for Africa is to improve the nutrient status of agricultural lands, of which many are acidic, low in phosphorus and high in toxic aluminum (Thomson, 2008) and as such weakens the continents food security. Soil as a natural resource is a vital abiotic component in all forms of agrarian practices. Once soil nutrients are depleted, its contributions to the growth of food crops become useless; it is very expensive to rehabilitate it (Oldeman, 1998). Sub Saharan African region has recorded rapid levels of soil degradation and erosion more extensive than in other continents of the world due to misuse of land by farmers and livestock keepers (Mortimore and Harris, 2005). Soil erosion is most often linked with soil nutrient depletion which is considered as one of the biophysical root cause of declining per capita food production in SSA (Drechsel et al., 2001). It will take more than proper soil management to sustain food security in Africa let alone increase it (Drechsel et al., 2001). The question is "will green biotechnology be able to overcome such unfavorable conditions"?

Constraints to agricultural development in SSA are soil nutrient depletion (Drechsel et al., 2001). There is no doubt that green biotechnology is environmentally sustainable on the part of preserving declining abiotic natural resources soil water and arable land as well as forests and other biomes which are often cleared to extend agricultural lands. Furthermore, Goblier (1997) noted that sub Saharan Africa which includes many of the world's poorest countries is likely to more than double in population size by 2050. With economies of sub Saharan Africa mostly dependant on agriculture especially in the eastern, western and central Africa, soil degradation is a threat to overall development (Scherr, 1999). According to Kullaya (2005), environmental biotechnology can be used to assess the integrity of ecosystems, transform pollutants into benign substances and develop environmentally-safe manufacturing and disposal processes. The potential of biotechnology in the production of bio-fertilizers is in two folds namely: nitrogen fixation and bioconversion. With the former, leguminous rhizobium is able to fix atmospheric nitrogen to produce nitrates, which are readily absorbed by the plant as fertilizer. The bacterium is cultured in the laboratory, and then multiplied on appropriate medium, for instance on seed of the respective leguminous plant before planting. Bioconversion comprises the use of microorganisms in processing organic residues for the production of energy and biofertilizers where bacteria are used to decompose many forms of garbage resulting in the production of energy and fertilizer. Regarding bioremediation, living organisms or their products could be used to degrade many forms of garbage to produce energy and bio-fertilizers. The technology can also be used to degrade waste into less or non-toxic products or to remove heavy metals like mercury form polluted soils. This offers an attractive alternative for waste disposal because it is non-polluting and it uses renewable resources as inputs. It has also been proven that some agricultural biotechnology applications contribute to environmental protection because of reduced use of agricultural inputs such as pesticides and herbicides (BurachiK, 2010).

Cultivation of transgenic crops like maize, rice, wheat, soybean and cotton are among the top priorities for the agricultural biotechnology industries (Ozor, 2008). Asante (2008) states that Canadian scientists have created a tomato that grows in water nearly half as salty as the ocean. Genetically, modification allows for the creation of crops with genes that resist damage due to unexpected frost or long periods of drought. These GM crops will allow more food to be produced per plot of land, and in regions that suffer from a lack of arable land, these crops will provide food where formally could not be produced (Chetty and Viljoen, 2007).

Biological crop pests cause serious economic losses. In Africa, the most prevalent parasites are insect pests, plant pathogenic root-knot nematodes, viruses and parasitic plants (Runo et al., 2011). Viruses have been known to be among the major limiting factors in the production of Africa's main food and commercial crops (ASSAF, 2010). Among the diseases caused include maize streak virus (MSV) of *Zea mays* L) which has rendered the production of maize in some parts of Africa virtually impossible (Wambugu, 1999; Bosque-Perez, 2000), cassava mosaic virus disease (CMVD), cassava brown streak virus disease (CBSD) in East and Central Africa (Gibson et al., 1996). Runo et al. (2011) indicated that small farm holders are struggling to overcome these parasitic constraints which increase crop losses.

GREEN BIOTECHNOLOGY ON AFRICAN SOIL

Developing countries are already benefiting from the scientific advances in plant biotechnology (Ismael et al., 2002; Kikulwe et al., 2005; Toenniessen et al., 2003; Vuylsteke et al., 1993). The most widely used GM technologies involve herbicide tolerance (HT) applied in soybean and canola, and insect resistance, based on genes isolated from *Bacillus thuringiensis* (Bt), applied in maize and cotton. According to Thomson (2008), insect-resistant varieties of maize and cotton suitable for the subcontinent have been identified as already having a significant impact. In the African context, GM technology so far has been deployed only in South Africa, Zimbabwe, Egypt, Kenya, Burkina Faso, Uganda and Malawi, and Mauritius. Of these few countries, South Africa, Egypt and Burkina Faso have commercialized their crops (Eicher et al., 2006; ASSAF, 2010). Since its introduction, GM technology has been found to reduce losses of maize incurred through damage by stem borers (Wanyama et al., 2004). Transgenic wheats with high Glutamate dehydrogenase, for example, yielded up to 29% more crop with the same amount of fertilizer than did the normal crop (Smil, 1999). Local farmers are benefiting from tissue-culture technologies for banana, sugar cane, pyrethrum, cassava and other crops (Wambugu, 1999). Peanuts or peaches without their well known allergens and fats and oils that lead to less obesity and thereby less repeated heart failures will be of great success (VonBraun, 2007).

As a sustainable solution to child malnutrition in many African countries, the Africa biofortified sorghum project, a grand challenge in global health project, is undertaking research to biofortify sorghum in terms of protein and micronutrient quality using genetic engineering (Henley et al., 2010). This is to aid children in meeting their energy and protein requirements through sorghum porridge. Other studies on biofortification have succeeded in producing rice with a higher iron content, which was shown to improve the iron deficiency of consumers which could aid millions of women and children who are anaemic (Haas et al., 2005). Another important research advance has been the creation of a strain of "golden" rice which contains very high levels of β-carotene (pro-vitamin A) by the Swiss Federal Institute of Technology, which will contribute to fight against avitaminosis which affects a high proportion of people in most African countries (ASSAF, 2010; Ye et al., 2000).

According to Kelemu et al. (2003) biotechnology issues specific to the African public must include crop and animal productivity, food security, alleviation of poverty and gender equity, which is what the biotechnology case study in the Makathini flats achieved. In the Makathini flats in northern KwaZulu-Natal during 1999 to 2000 farmers in this area, half of whom were women, obtained a 77% higher returns from growing BT cotton (GM crop variety) than from growing conventional varieties (Tonukari and Omotor, 2010). Additional gains by the Bt adopters was in terms of lower insecticide costs. Serious insect pests were one of the major limiting factors to productivity. Among the most damaging of these were the bollworm species: American bollworm (*Helicoverpa armigera*), Red bollworm (*Dip-aropsis castenea*) and Spiny bollworm (*Earias biplaga* and *Earias insulana*) (Ismael et al., 2002). There is no doubt that agricultural biotechnology can make very substantial contributions toward increasing food production by rural resource-poor farmers, while preserving declining resources such as forests, soil, water, and arable land (Bunders and Broerse, 1991) and reducing incidence of pests and diseases.

In Argentina, the first GM crop, glyphosate-tolerant soybean (GTS) brought a significant improvement in the agronomic practices, which increased enthusiasm in the adoption. Operations were drastically simplified as farmers discontinued the use of complicated mixtures of expensive and more toxic herbicides and switched to a low toxicity, single chemical, friendlier to the environment and to them. Additionally, seriously noxious weed infested land which had been set aside could be brought back to production (Burachik, 2010). It was also added that the use of GTS has shown a very convenient synergy with no-till farming, which was widely used (Peiretti, 2004). It is highly accepted that low- and no-till farming reduces both soil erosion and emission of greenhouse gases, thus, enhancing agricultural sustainability through a better soil organic conservation and reducing the impact on climate change. In addition to other benefits it was estimated that the release of GTS has contributed to the creation of almost a million jobs economy-wide, representing 36% of the total increase in employment over the 1996 to 2006 period (Trigo and Cap, 2006). The Bt maize being used is of a better grain quality, which increased farmers' competitiveness and a healthier product, as mycotoxin levels were consistently well below mandatory regulations (Barros et al., 2009; De la Campa et al., 2005).

There was also a longer sowing/harvest windows, on account of a longer stand in that plant were not damaged by maize borers. This increased yield allowed harvesting at a higher grain dry matter weight and reduced drying costs and environmental contamination, hence improving sustainability (Burachik, 2010).

Huesing and English (2004) listed some of the benefits of Bt as shown in Table 1. Tables 2 and 3; and also Figure 2 shows the purposes of GM, the traits of specific crops and some of the countries involved in the technology.

Farmers are paying premium prices for the use of the technology because of increased productivity and efficiency gains (Brookes and Barfoot, 2008). South Africa is estimated to have increased farming income from biotech maize, soybean and cotton by US$383 million between 1998 and 2007, with benefits for 2007 alone estimated at US$227 million. Brookes and Barfoot (2006) indicated that GM technology has had a very positive impact on farm income derived from a combination of enhanced productivity and efficiency gains (Table 4). In 2005, the direct global farm income benefit from GM crops was $5 billion. If the additional income arising from second crop soybeans in Argentina is considered, this income gain rises to $5.6 billion. This is equivalent to the addition of 3.6 and 4.0% to the value of global production of the four main crops of soybeans, maize, canola, and cotton, which is a substantial impact. Since 1996, farm incomes have increased by $24.2 billion, or $27 billion inclusive of second crop soybean gains in Argentina.

Biotechnology can curtail another growing phenomenon that entails the increase in number of environmental refugees in Africa. Environmental refugees are people who can no longer gain a secure livelihood in their homelands due to drought, soil erosion, deforestation, desertification and other environmental problems together with associated problems of population pressures and profound poverty (Myers, 2002). With the ability of GM crops to grow under unsuitable harsh atmospheric conditions, they will definitely decrease the number of environmental refugees.

Concerns of biotechnology have put considerable constraints on the opportunity for extended commercial use in Africa. The critics of biotechnology claim that Africa has no chance to benefit from biotechnology, and that Africa will only be a dumping ground or will be exploited by multinational companies. The priority of Africa is to feed 'her' people with safe foods and to sustain agricultural production and the environment (Wambugu, 1999). According to Braun (2002), the organic farming movements have spread fears concerning the use of genetically modified foods and as a result have hindered the potential of GM anywhere in the world.

Many that are in opposition to GMO's and in favour of organic foods have argued that organic foods are healthier than GM foods, Braun (2002) argues that agriculture has never been natural due to the use of chemicals and fertilizers even in organic farming practices. Without chemical fertilizers, there would be far less food produced in the world than there is currently.

Table 1. The commercial, economic, and social benefits of Bt crops (Huesing and English, 2004).

Impacted area	Current	Future
Agricultural practices	Less and/or more efficient use of pesticides. More efficient use of water. Increased productivity.	More diversified agricultural products. Quality traits crops. Pharmaceutical crops.
Government and social	Macroeconomic gains Higher efficiency of agricultural sector Improved food and feed quality.	Increased consumer confidence. Greater improvements in food and feed quality.
Economic benefits—growers	Improved control of insects and weeds Reduced input costs such as labor and chemical application costs. Increased yields Reduced exposure Increased incomes	Trends will continue. Movement away from subsistence farming as farmer incomes improve and more modern agricultural practices are adopted.
Economic benefits—consumers	Reduced food costs Less pesticide usage Lower pathogen loads	Greater range of affordable food choices, including quality traits

Table 2. GM crops developed for various purposes (Malik and Saroha, 1999).

Purpose/reason	Trait	Transgenic crop
Improved productivity	Drought tolerance	Maize
	Salinity tolerance	Rice
	Aluminium tolerance	Tobacco
	Disease resistance	Rice
	Stress and insect resistance	Cotton
	Herbicide tolerant	Cotton, maize canola and soybean
Health and nutrition	Vitamin A content	Rice mustard
	Iron content	Rice
	Reduced toxins	Cassava

Table 2. Contd.

Value added traits	Colour change Flavor change Shelf life	Flowers Tomato Tomato
Plants for medicinal purposes	Vaccine production	Banana, Potato, Tomato Tobacco
Plants for industrial purposes	Biodegradable plastic production Starch production	Maize Maize Sugarcane
Self-regulating plants	Limiting gene flow to related and/or wild species	Oilseed rape
Removing toxic compound from environment (bioremediation)	Mercury pollution Cadmium contamination	Arabidopsis thaliana Tobacco

There is also no solid data to support the organic movements' arguments that their products are healthier (Trewavas, 2001). In the long run the organic movement is doing the environment a huge disfavour by being categorically against GMO's since many of the transgenic crops have potential to improve the sustainability of farming, including organic farming (von Braun, 2007).

ENVIRONMENTAL (BIODIVERSITY) RISKS

In the 1970's when genetic engineering experiments with micro-organisms were first being developed, many molecular biologists believed that the process was unsafe. Micro organisms were to be strictly contained and prevented from being released into the environment (Ozor, 2008). Environmental risks that need to be considered include the possible loss of biodiversity, detrimental effects on natural food chains and the emergence of aggressive pathogen populations especially in developing world where likelihood of transgenic seeds escaping into the wild through cross-pollination is high (Abah et al., 2010). GM crops can threaten the centre of crop diversity (Rissler and Mellon, 1993) or outgrow a local flora to the detriment of native species; this is evident today. Genetically modified technology could result in the contamination of crops through gene transfer refer to as genetic pollution through cross pollination which can lead to the creation of hard to eradicate super weeds (Altieri 2002; Uzogara, 2000). The putative presence of transgenes in Mexican maize landraces and the interpretation that this presence may reduce the value of maize genetic resources (Quist and Chapela, 2001) has fuelled the debate about genetic resources in centre of crop diversity.

Some European and African countries are also very skeptical about having GM foods incorporated in the diet of their population. There have been instances where some African and European countries have rejected GM foods into their borders, and refused to renew the approval of the product. In Europe, is the case of MON810 Monsanto's line of maize developed through genetic modification to resist the corn borer, an insect pest in Europe (Stephenson, 2010). Germany's law allows the banning of a product if it potentially poses harm to the environment (Stephenson, 2010). European food safety authority's (EFSA's) findings indicate that MON810 (Monsanto pesticide produce GM maize) is environmentally safe (Stephenson, 2010). Currently, there are six countries that have banned MON810. Germany being the last and

Table 3. Transformation events grouped by country, crops and phenotypic category (Cohen, 2005).

Continent	Country	Number of event	Crop	Phenotypic category B
	Egypt	17	Cotton, cucumber, maize, melons, potatoes, squash, marrow, tomatoes, watermelons, wheat.	AP, FR, FR/HT, HT/IR, IR, OO, PQ, VR
	Kenya	4	Cotton, maize, sweet, potatoes.	HT, HT/IR, OO, PQ, VR
Africa	South Africa	20	Apples, grapes, lupin, maize, melons, pearl, millet, potatoes, sorghum, soybeans, strawberry, sugar cane, tomatoes, indigenous vegetables.	AP, BR, FR, HT, HT/AP, IR, PQ, VR
	Zimbabwe	5	Cotton, cowpeas, maize, sweet potatoes, tomatoes.	FR, HT/VR, VR
	China	30	Cabbage, chilli, cotton, maize, melons, papayas, potatoes, rice, soybeans, tomatoes.	AP,FR, IR, VR
	India	21	Cabbage, cauliflower, chickpeas, citrus, eggplant, mung beans, muskmelon, mustard/rapeseed, potatoes, rice, tomatoes	AP, FR, HT/AP, IR, IR/BR, OO, PQ, VR
Asia	Indonesia	14	Cacao, cassava, chili pepper, coffee, groundnuts, maize, mung beans, papayas, potatoes, rice, shallot, soybeans, sugar cane, sweet potatoes.	AP, FR, IR, PQ, VR
	Malaysia	5	Oil, palms, papayas, rice	HT, IR, VR
	Pakistan	5	Cotton, rice	HT, IR, PQ, V
	Philippines	17	Bananas and plantains, maize, mangoes, papayas, rice, tomatoes.	AP, OO, VR
	Thailan	7	Cotton, papayas, pepper, rice.	AP, BR, IR, VR
	Argentina	21	Alfalfa, citrus, potatoes, soybeans, strawberry, sunflowers, wheat.	AP, BR, FR, IR, IR/BR, OO, PQ, VR
Latin America	Brazil	9	Beans, maize, papayas, potatoes, soybeans, strawberry, sunflower, wheat.	Alfalfa, citrus, potatoes, soybeans, strawberry, sunflowers, wheat.
	Costa Rica	5	Bananas and plantains, maize, rice	AP, IR, VR
	Mexico	3	Bananas and plantains, maize, potatoes.	IR, VR
Total		201		

An event is defined as the stable transformation—incorporation of foreign DNA into a living plant cell—undertaken by a single institute among the participating countries, thereby providing a unique crop and trait combination. B Phenotypes are defined as follows: AP, agronomic properties; BR, bacterial resistance; FR, fungal resistance; HT, herbicide tolerance; IR, insect resistance; OO, other; PQ, product quality; VR, virus resistance.

has not given sound scientific evidence, however, Spain has planted MON810 without experiencing negative effects (Stephenson, 2010). Southern African countries in 2001 also rejected food aid that was genetically modified from the U.S during a severe drought partly due to environmental concern. However, scientists generally agree that the possibility of potential actual environmental risk due to pollen disbursal is extremely remote

Table 4. Global farm income benefits from growing GM crops 1996-2005 (million US $). (Brookes and Barfoot, 2006).

Trait	Increase in farm income 2005	Increase in farm income 1996 to 2005	Farm income benefit in 2005 as % of total value of production of these crops in GM adopting country	Farm income benefit in 2005 as % of total value of global production of these crop
GM HT soybeans	2,281 [2,842]	11,686 [14,417]	5.72 [7.1]	4.86 [6.05]
GM HT maize	212	795	0.82	0.39
GM HT cotton	166	927	1.16	0.64
GM HT canola	195	893	9.45	1.86
GM IR maize	416	2,367	1.57	0.77
GM IR cotton	1,732	7,510	12.1	6.68
Others	25	66	n/a	n/a
Total	5,027 [5,588]	24,244 [26,975]	6.0 [6.7]	3.6 [4.0]

HT=herbicide-tolerant, IR=insect resistant, Others = Virus-resistant papaya and squash, rootworm-resistant maize.Bracketed figures include second crop benefits in Argentina. Totals for the value shares exclude 'other crops' (that is, relate to the 4 main crops of soybeans, maize, canola and cotton). Farm income calculations are net farm income changes after inclusion of impacts on costs of production (for example, payment of seed premia, impact on crop protection expenditure)

Table 5. Biotechnology research projects in selected sub-Saharan African countries (FAO).

Country	Key Institute with agri-biotech research capacity	Biotech research project/ programme					
		Total	Type of technology		Area of application		
			GMO	Non-GM	Crop	Livestock	Forestry
South Africa	10	92	42	50	58	8	26
Nigeria	7	72	5	67	72	0	0
Kenya	6	36	10	26	31	1	4
Zimbabwe	6	29	2	27	27	2	0
Ghana	6	28	1	27	25	0	3
Uganda	4	25	3	22	21	3	1
Ethiopia	4	22	0	22	9	6	7
Tanzania	4	22	1	21	13	8	1
DR Congo	2	11	0	11	6	1	4
Malawi	4	10	1	9	9	0	1
Namibia	3	2	0	2	2	0	0

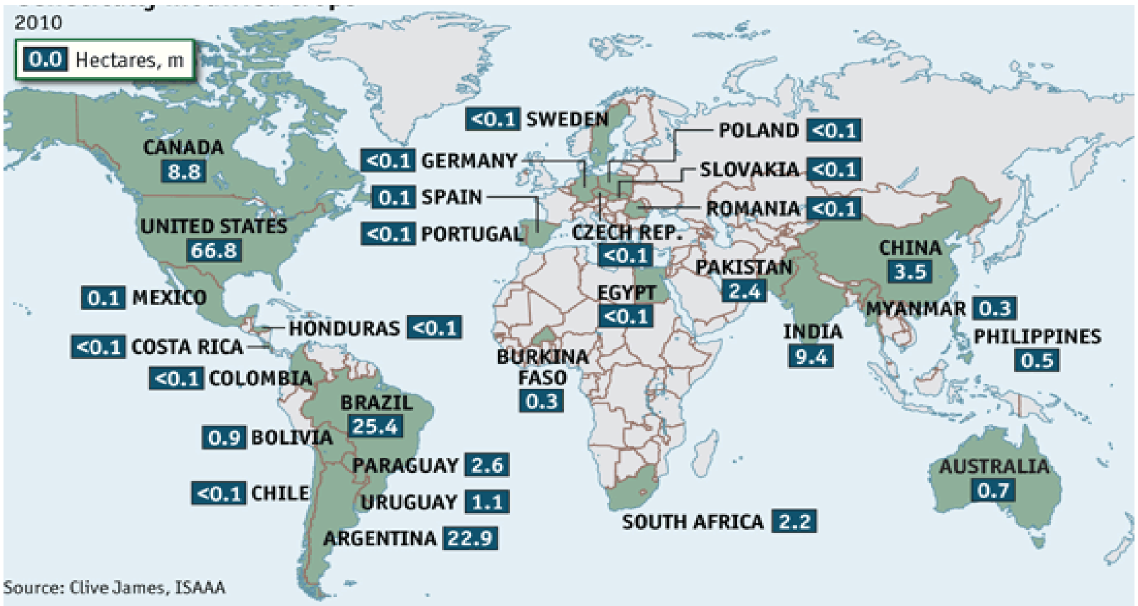

Figure 2. Major genetically modified crop countries in the world (James, 2010).

(Stephenson, 2010).

CONCERNS

Social

The concerns about GM products as biological weapons (Atlas, 1998; Dando, 2011; Poupard and Miller, 2006) intended for killing or causing disease on target victims needs to be highlighted. Dando (2011) noted that there is so much debate about biological weapons in line with the possibility that genetic modification processes established by benignly intended civil science could later be misused by others as instrument of bioterrorism. Much of this debate of biological weapons and bioterrorism has taken place in the United States (Dando, 2011) and it is a major possible threat that all countries should take note of GM labelling and emphasized that it will prove benefit to consumers. These group advocate beliefs that will give consumers the right to choice whether or not to consume GM foods (Rousu and Huffman, 2001).

Even though the concern is highly exaggerated there is the need to draw attention of the scientific sphere to the risk involved. This has been observed in experiments with pathogens warrant review on bio security where structures have been put in place to deal with such an oversight system. Asante (2008) suggested that African governments can regulate the acceptance and adoption of GM food and related technologies, by having experts who can critical analyze, evaluate and choose the best safest technology needed for human health. However, the long term impact on the ecosystem should not be overlooked in instances where organisms can stay in the soil over years and evolve into hazardous pests.

Ethical

Transferring animal genes into plants raises important ethical issues for vegetarians and religious groups which find this highly unacceptable (Asante, 2008). In Africa, many communities and consumers express ethical concerns about playing God, as plants are transformed in unnatural ways and about the implications for traditional beliefs and values (Asante, 2008; UNEP, 2007). Feeding on crops with human genes is more or less practicing cannibalism since humans are the ultimate users of such crops and their products.

Health

Concerns as to whether GM foods pose allergy risks is not new; many are aware that it involves the insertion of foreign genes into an organism in this case a plant crop. From the viewpoint of many, genetic engineering is seen as unnatural and unnecessary in food production (Ozor, 2008). According to Uzogora (2000) GM is one of the most serious threats to human civilization. In Africa, many governments are skeptical of genetically modified foods. Eicher et al. (2006) and Bodulovic (2005) referred to an occurrence when Southern African region was faced with serious drought conditions and critical food shortages and were in desperate enough position to require large amount of food. Zambia along with the rest of Southern African governments (Malawi, Zimbabwe, Mozambique included) under such circumstances rejected United Nation's food-aid supplies due to suspicions of food-aids being genetically modified. Skepticism as to whether the GM foods harnessed possible health threats, trade concerns, and environmental concerns needs to be dealt with for good. According to Luthy (1999) analytical methods for authenticity testing have been described for all types of foods and can give us important indications for analytical strategies to be developed for the detection and quantization of GM foods, newly introduced traits or marker genes should be detected by DNA or protein based methods (Luthy, 1999).

According to Ozor (2008), the safety of the human food supply is based on the concept that there should be a reasonable certainty that no harm will result from its consumption. Foods or food ingredients derived from GMOs must be considered to be as safe as, or safer than, their traditional counterparts before they can be recommended as safe. This is however, not enough to quell fears surrounding commercialization of GM foods in certain countries on the African continent.

It is no crime for people to be suspicious of genetically modified organisms. A study has revealed that volunteers who ate one meal containing genetically modified soya had traces of the modified DNA in bacteria in their small intestines (Poulter, 2002). According to Asante (2008), eating GM food can change the genetic make-up of one's digestive system and could put someone at risk of infections that are resistant to antibiotics. Although, most genetic modified organisms (GMOs) are regulated, if falls in the wrong hands can or may be used for hostile purposes or in armed conflict (Asante 2008). Even a small imbalance in these natural substances could have serious consequences, inducing fear, fatigue, depression or incapacitation (Dando, 2011). Starlink is an incident which took place in 1998 in the U.S where starlink corn specifically planted to serve as animal feed accidentally spread into the human food chain and as a result had to be withdrawn from the market (Braun, 2002). People claimed to have suffered an allergic attack from the product, but laboratory studies did not confirm even a single case of allergy (Braun, 2002). A major threat that all countries should take note of is the issue of bioterrorism where GM plants are used as biological weapons (Dando, 2011).

Financial

Ozor (2008) substantiated the adverse effect that could result in the adoption of genetically modified seeds in the developing countries. Ozor (2008) noted that biotechnology developments need high inputs of finance which are in short supply in most developing nations. Furthermore, Ozor (2008) stated that the likelihood of agricultural biotechnology widening the socio-economic chasm between developed and developing nations is very high. Leisinger (1996) made us aware of the possibility that genetically produced vanilla flavouring could displace 70,000 small farmers in Madagascar; genetically improved cocoa varieties, thousands of small holder farmers in West Africa and other countries within the continent. From this, one can foresee a huge unemployment rate crippling the economy. The question is can not African governments pull resources together and help the farmers if such a scenario arises?

Political

Socio-economic and political sides embrace the overview anxiety. Those related to human health from such things as allergens and toxins, as well as environmental impacts from gene escape, altering the balance in living organisms and ethical concerns based on religious and cultural values. Thus, to a very great degree, it is the duty of a nation to ensure the safety of GM products using all required expertise. Tonukari and Omotor (2010) indicated that food security is vital for every individual, home, community and nation and that in developing countries, it could be considerably enhanced, by increased investment and policy reforms. He further noted that there is need for government and public-private collaborations to invest in agricultural biotechnology-based companies, researches, or initiatives, in order to make the gene revolution beneficial to developing countries.

Curtis et al., (2004) noted that in the light of scientific innovation (including food safety) when a trust in government regulators is established there is always

Table 6. GM crop regulatory approvals in South Africa (AgBios GM Database 2007).

Crop	Trait		
	Insect resistance (IR)	Herbicide resistance (HT)	Stack IR/HT
Maize (*Zea mays*)	2	3	4
Cotton (*Gossypium hirsutum)*	2	1	-
Soybean (*Glycine max*)	-	2	-

evidence of general acceptance. According to Burachik (2010), the adoption of GMO agricultural technology in Argentina, the second largest grower of genetically modified (GM) crops has resulted from several factors. These comprise the political willingness to study this new technology and crops as well as the recruitment of sound professionals and scientists to perform the task. These professionals with different expertise have produced the necessary regulatory framework to work with these new crops. Farmers played a decisive role, as adopting this new technology solved some of their agronomic problems, helped them perform more sustainable agronomic practices and provided economic benefits. It is emphasized that all the progresses would not have been possible without a rational, science-based and flexible regulatory framework that makes sure that the GM crops were safe for food, feed and processing. Thus, the GM adoption and sustenance needs a holistic approach by all parties involved.

The great majority of agricultural biotechnology research in Africa is on crop improvement, although, not all rely on the use of (GM) technology as shown in Table 5. Nigeria hosts over 60 projects exploring non-GM biotechnology for example, micropropagation of cassava, date palm and ginger (FAO). Morris (2011) reported that in sub-Saharan Africa, the capacity to develop GMOs and ensure they meet stringent regulatory requirements poses a limitation. Most African governments contribute little to science and technology either financially or through strong policies. This leaves the determination of research and development priorities in the hands of international funding agencies. These funding sources come in two different directions either in support of GM technology or biotechnology, overlooking the fact that the two work hand in hand and not in isolation. In line with this observation, it was proposed that African governments as well as external funding agencies should concurrently consider biotechnology and GM technology in order to offer sustainable development in Africa and provide adequate support to the development of the capacity to research and develop commercialize GMOs in the region. South Africa is doing well in the area of commercialization as shown in Table 6; however, more countries are expected to follow suit.

CONCLUSION

Genetically modified technology has faced many critics and has equally enjoyed the support of fanatics and thus, sparked many debates across the globe. The opposition goes as far as to condemn its use, for reasons of food safety, due to the possible negative impacts it may have on human health and the threat of contaminating plant species through cross-pollination, especially in developing countries where vast expanses of natural plant biodiversity is located. Other issues include bioterrorism and socio-economic well being of the people; the later takes into account the fear of exploitation that could result in the monopolization of African agricultural sector by multinational corporations and also the possibility of exacerbating the socio-economic gap between the developed and the developing world.

However, those in favour of its use on the African continent bring to our foremost understanding that subsistence and commercial agriculture is the back bone of the economy and food security in sub Saharan Africa. They claim that the African continent, housing majority of the world's poorest countries in the world is faced with a myriad of social, economic and environmentally related issues that cannot sustain the livelihoods of the existing majority population. The outcome of such issues in the midst of an ever increasing population are seen in the form of poverty, malnutrition and stunted growth and if there is any progress at all, it tends to be in a diminishing trend. The forward-looking groups that argue in favour of GM technology hold the view that traditional farming methods and system of the green revolution is not helping to increase agricultural crop yields due to environmental challenges such as persistent drought, poor soils, prevalent crop diseases and pests. Thus, the strength of preservation of the biodiversity for generations to come will lie on a modern dimension that will improve food security and enhance sustainability in agriculture and hence, genetically modified crops are the answer.

Looking at it in a broader perspective, the way forward of genetics and genomics reorganization and alteration will not only lead to food increase but also help to generate suitable living resources for the development of medicine to cure deadly diseases as HIV/AIDS, and to obtain renewable energy resource of suitable characteristics to produce desired lipid quality and quantity for biofuel. The GM technology enables humans exercise their dominion over other living and nonliving resources as well as any negative interactive products from the two that might debilitate against our progress. The skeptism in developing countries about GM food is not about arrogance but lack of knowledge that generates fear. Thus, the horror and the threat that are associated with the acceptance of GM technology could be eradicated or expunge from the mindset of the citizens through education and awareness programmes using social network services (including face book) to all sectors of the economy stating simply and clearly the necessity and the benefits of GM biotechnology. This should be supported by a laid down assessment system. GMO technology definitely holds great potential in food security for Sub Sahara Africa and as such must not be taken lightly.

ACKNOWLEDGEMENTS

My thanks go to Mr Kofi Gyan Quartey for his immense input and all who critically read the manuscript.

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