Chapter 2
Genetically Modified Crops in Africa

Georgina D. Arthur and Kwasi S. Yobo

Abstract Hunger and malnutrition are flammable pertinent issues that hinder progress of a nation and become an increasing risk. Biotechnology and food security have very good relationship both in the present and the future, concurrently embracing technology that offer new opportunities with increase crop and animal production. Additionally, they offer capacity building, collaboration, research and ensure sustenance. There is the need to engage and address exploration of new techniques and encourage various scientific and community debates with the support of respective governments. The way forward is to review biotechnology tools including biosafety processes, policies and proper implementation to sustain biodiversity.

Keywords Biotechnology · Environmental safety · Africa · Food security · Biodiversity · Genetically modified organisms · Biosafety

2.1 Introduction

West Africa, East Africa Central Africa and Southern Africa form the Sub Saharan region of the African continent. The majority of Agricultural practices in this region are characteristic of typical developing region where agriculture is still an economic backbone. The agriculture economy employs about 60 % of the workforce and contributes an average of 30 % of gross domestic product (USAID 2003). Agricultural growth rates for SSA declined in the 2000s and food insecurity is still a concern, as the prevalence of malnourishment has only dropped from 34–30 %

Dedicated to all who are pursuing to sustain biodiversity

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in two decades. Agricultural development in sub-Saharan Africa (SSA) also faces the daunting challenge of climate change and increasing climate variability in most vulnerable areas (Thornton et al. 2011). The productivity of crops grown for human consumption in SSA is very much at risk due to the incidence of pests, especially weeds, pathogens and animal pests (Oerke 2006).

Staple crops cultivated by means of organic methods such as the cassava, maize, sorghum, millet, cowpea, groundnuts amongst others are at risk due to crop pests and their destructive tendencies that compromise high yields. Soil nutrient depletion is considered as the biophysical root cause of declining per capita food production in sub-Saharan Africa. According to Drechsel et al. (2001) data collected in 37 countries in SSA confirm a significant relationship between population pressures, reduced fallow periods and soil nutrient depletion including erosion. Another factor that is placing immense pressure on agricultural lands and crop yields per hectare is the increasing human population in Sub Saharan Africa. According to the United Nations (2011) fertility in SSA stood at 5.1 births per woman between the periods of 2005–2010. This high fertility combined with declining mortality has resulted in rapid population growth of 2.5 % per year. The UN projects the sub-Saharan population to grow from 0.86 billion in 2010 to 1.96 billion in 2050 and 3.36 billion in 2100. Bongaarts and Casterline (2013) noted that most important step required to make progress in addressing high and unwanted childbearing and rapid population growth is for policymakers in Africa to realize that the current demographic trajectory is a major obstacle to their countries' development. With respect to increasing population densities, it is argued that more than proper soil management will be required to sustain food security (Drechsel et al. 2001). Since SSA maintains the highest proportion of malnourished populations in the world, with one in three people chronically hungry, it is believed by GM supporters that it is through the formalised implementation and cultivation of GM crops, that crop losses can be curtailed. GM crops are defined in this chapter as new varieties of crop species developed by molecular modification through the insertion of foreign genetic materials (Jacobsen et al. 2013). Although only South Africa and Burkina Faso are the countries in SSA to have formalised the implementation of GM crop cultivation, countries such as Kenya, Ghana, Nigeria, and Uganda are involved in developing GM crops that are drought resistant, pest resistant, efficient water use, nutrient rich and high yield than conventional crops. This chapter describes the critical cogitations of GM crop in Africa to assess progress in various countries with an objective of the prospective role that GM crops can play in achieving better food security in the sub region of the African continent.

2.2 What is Biotechnology?

Biotechnology is not new to mankind and has been around for thousands of years in which mankind has been cross breeding and manipulating living organisms to meet his own dietary and industrial needs. Food fermentation for example is evidence of one of the oldest known uses of biotechnology (Campbell-Platt 1994). The baking of yeast-leavened and sour dough breads also represents one of the oldest biotechnical processes, together with the brewing of beer, wine, and the production of yoghurt and cheese (Fleet 2007). These forms of biotechnology are labelled as "traditional".

Current process of biotechnology in its widest sense makes use of the improvement of cereal grains and starter cultures by recombinant DNA technology, through the use of enzymes as processing aids, to application of the most advanced batch and continuous fermentation technologies (Linko et al. 1997). Modern methods of biotechnology for the purpose of altering or modifying the genes of organisms include; Red biotechnology, which involves the medical processes, white Biotechnology which is also known as Gray Biotechnology, which is used for the industrial processes, Green Biotechnology which involves the processes and development of pest-resistant crops and disease resistant animals, and finally, Blue Biotechnology which is used for marine and aquatic processes (DaSilva 2004). Biotechnology also includes the application of a wide variety of biological, biochemical, bioengineering, genetic, microbiological and control techniques. Undeniable evidence in the form of vast bodies of scientifically proven literature demonstrates that biotechnological tools such as tissue culture, genetic engineering and molecular breeding (marker-assisted selection) continue to provide promising opportunities for achieving greater food security while improving the quality of life (ISAAA 2009). Crop genetic engineering process shown in Fig. 2.1

2.3 Benefits and Concerns in SSA

The use of genetically modified (GM) crop technology in tackling food security problems and poverty reduction in Africa (south of Sahel) has been debated upon countless occasions. Although policy makers from developing countries have increasingly considered GM crops as a potential tool for increasing agricultural productivity, contentious debates over both the benefits and concerns of implementing GM crops have hindered its implementation. There are currently 29 countries in the world that are cultivating GM crops. Out of these 29 countries 19 are developing countries (James 2011). Out of the 19 developing countries, only three come from the entire African continent. In Sub Saharan Africa only two countries have approved commercial cultivation of GM crops namely South Africa and Burkina Faso (Racovita et al. 2013). The development of GM crop varieties in Africa has raised a wide range of new legal, ethical and economic questions in agriculture (Azadi and Ho 2010). GM crops are promoted as the solution to the prevalent issues of food security and low agricultural productivity in sub Saharan Africa and other parts of the developing world. The promotion is however not restricted to the developing countries but also the first world. On the one hand, Sub Saharan African farmers are encouraged to accept and implement GM crops because of their higher productivity, while organic farming is encouraged because of socio-economic and

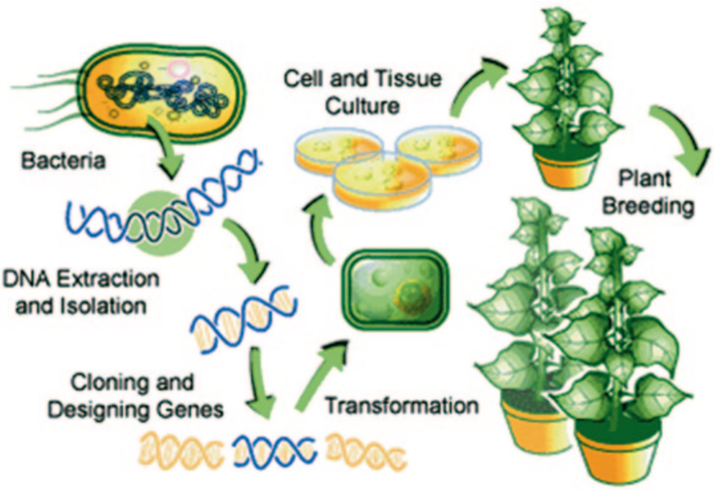

Fig. 2.1 Crop genetic engineering includes: *1* DNA isolation, *2* gene cloning, *3* gene design, *4* transformation, and *5* plant breeding. (Source: http://oregonstate.edu/orb/terms/genetic-engineering)

environmental considerations (Azadi and Ho 2010). The types of concerns that accompany GM crops are from the time they are planted right through to the time that they are consumed. Concerns of GM crops are present in the divisions pertaining to both environmental health and human health. They have been labelled countless times as a potential risk to animal and human health because of their potential toxicity and allergenicity (Racovita et al. 2013).

The following according to Malarkey (2003) are four concerns within food and feed safety issues that GM crop cultivation bring about:

1. The inherent toxicity of the novel genes and their products.
2. The potential to express novel antigenic proteins or alter levels of existing protein allergens.
3. The potential for unintended effects resulting from alterations of host metabolic pathways or over expression of inherently toxic or pharmacologically active substances.
4. The potential for nutrient composition in the new food differing significantly from a conventional counterpart.

Other reasons opposing GM include public attitudes, Socio-economic factors and intellectual property rights have also been raised (Racovita et al. 2013). There have been instances where traditional beliefs and ethical concerns have played a role in making the implementation of GM crops abominable. Coe (2014) noted that beliefs, habits and rituals are attached to religion and culture and are so deeply rooted that there is instant approval or disapproval of agribiotic products. Since the functioning and the future of biotechnology rest on network of a setup, awareness and understanding of how biotechnology relates to these ‘affiliations’ are imperative.

2.3.1 Potential Environmental Risks

Although the risks of genetically modified crops have sometimes been exaggerated or misrepresented, they do have the potential to cause a variety of health problems and environmental impacts (UCSUSA 2012). For instance, they may produce new allergens and toxins, spread harmful traits to weeds and non-GE crops, or harm animals that consume them (UCSUSA 2012). At least one major environmental impact of genetic engineering has already reached critical proportions: overuse of herbicide-tolerant GE crops has spurred an increase in herbicide use and an epidemic of herbicide-resistant "superweeds," (UCSUSA 2012).

With the evidence of escalating crop pests that suppress staple crop yields both on a subsistence and commercial scales, Sub Saharan Africa need crops that are disease-resistant, can fend off insect predators, and can withstand severe environmental conditions to produce larger crop yields (Pinstrup-Andersen and Schiøler 2001). It must be acknowledged that the implementation of GM crops alone will not solve the world's food problem, but they may be a useful element towards the fight against hunger. The contentious debates surrounding GM crops are a bottleneck to the implementation and probably the main reason that SSA is still lagging behind in accruing the benefits of this technology. Generally, people in developing countries should have ready access to information about both the benefits and the risks of the implementation of GM crops (Pinstrup-Andersen and Schiøler 2001). There have been many debates raising the concern as to whether the implementations of GM crops are feasible from both environmental and health perspective. Anti-GM activists argued that, due to monopoly power, GM crops would result in input costs and decrease diversity of seed choice, thereby forcing poorer farmers out and allowing a form of uniform, corporate-capitalist agriculture to dominate. These risks would be compounded, by potential threats to biodiversity from the spread of GM genetic material, and consumers could be at risk from potentially unsafe foods. Pro-GM advocates argued, by contrast, that GM seeds would reduce costs for farmers in a way, allowing rich and poor alike to benefit. By removing farmers from the burden of purchasing pesticides, for example, both health and economic benefits would result. No known health or environmental risks existed, they claimed, and, if governed by a streamlined regulatory system, all would be well, and the benefits of a 'gene revolution' would be realized.

Some commentators have dismissed anti-GM mobilizations as merely copycat responses by elite activists, using links with farmers' organizations as a way of raising funds (Paarlberg 2001).

2.3.2 Biosafety

Biotechnology is revolutionizing industrial and agricultural practice as the number of commercial biotechnology products is increasing each year. Simultaneously, several regulatory approaches are put in place to allow technological advancement while preserving public health and the environment. Developing and/or emerging countries often face major barriers to access biotechnologies and biotechnology derived products as they frequently lack the institutional capacities and professional competence in exercising regulatory oversight. To address this need, intensive biosafety capacity building is required. Different training approaches can be used to train individuals in biosafety ranging from long-term leading to a postgraduate certificate or a Master's degree, to short term courses. The UNIDO e-Biosafety program annually organized at the Marche Polytechnic University (MPU) in Italy and Ghent University (UGhent) in Belgium since 2006 has identified that proper institutional capacities need to be in place for countries to deal with the complex issues related to the adoption of GM-technology. It is therefore important to continuously bring to the attention of governments, developmental agencies and international organizations, the value of biosafety capacity development including training through formal degrees to encourage them to mobilize resources for these projects. From October 2006 to 2012, 100 students from 37 different countries participated in the course at the UGent and MPU network nodes. More than half of the students came from Africa (58 %), followed by Europeans (23 %). Only a minority came from Asia, Russia and Middle-East (10 %), Central and South America (7 %) and North-America (2 %). East African countries have been well represented and more than one fifth of the participants were Kenyans (Pertry et al. 2014).

Biosafety capacity building is a complex task and requires a multidisciplinary approach, the main components being human resource development, institutional and policy development for regulatory bodies and relevant research institutions, to enable them efficiently and effectively use biotechnology products particularly GM crops, microbes and/or their processed products. In the last decade, various developmental agencies and donors, notably the Food and Agricultural Organization of the United Nations (FAO), the Global Environment Facility (GEF) and the United Nations Environment Programme (UNEP), have been supporting the biosafety capacity building needs of developing/emerging countries through their technical assistance programs (FAO 2009; Hull et al. 2010). The range of activities include: (i) the development of national policies and formulation of regulations; (ii) GMO detection and monitoring including equipping of laboratories and harmonizing protocols among countries; (iii) facilitating effective communication and public awareness and (iv) human resource development in biosafety (Pertry et al. 2014). Figure 2.2 shows the various biosafety is stages in African countries.

2.3.3 Socio Economic Concerns

In October 2002 relief effort took an unexpected twist, as the governments of Malawi, Mozambique, Zambia and Zimbabwe rejected US food aid because of concerns

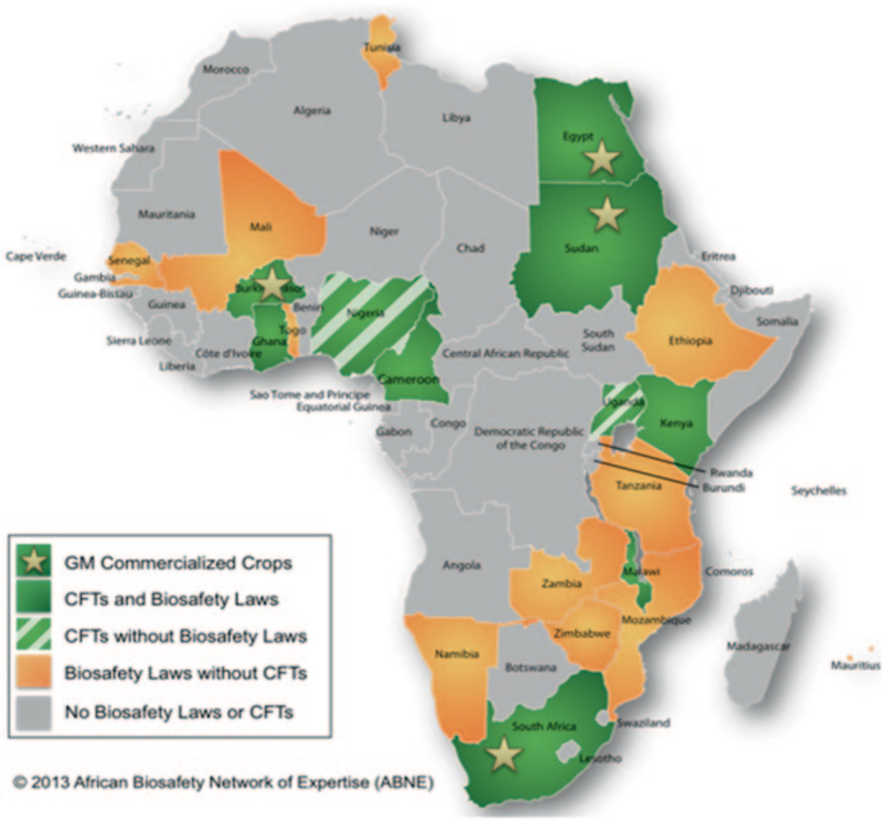

Fig. 2.2 Biosafety and confined field trials (CFTs) for GM crops at various stages in Africa

over the inclusion of genetically modified maize. Zerbe (2004) argues that genetically modified maize transported to Southern Africa in the form of aid, is not an initiative to end hunger in the region, but rather it was an initiative to expand market access and control of transnational corporations. In South Africa herbicide tolerant maize has been grown commercially since 2003, and in 2011, about 1 million ha out of total plantings of 2.71 million ha used this trait (Brookes and Barfoot 2012). From an economic perspective Sub-Saharan African farmers' opposition to the implementation of the cultivation of GM crops on their farm lands is understandable. Implementing the cultivation of GM crops would also disqualify their participation in certain European markets, or restrict them to providing only animal feed. Another problem with the adoption of GM crops seeds is that the farmers' ability to tap into the potential benefits of GM seeds can be limited by institutional issues (Falck-Zepeda et al. 2013).

2.4 Decision Making Tools to Aid Rejection or Implementation of GM Crops in SSA

Contentious nature of debates surrounding GM products have brought forth many suggested strategies that could help in the decision making process of whether to implement the cultivation of GM crops or not. Johnson et al. (2007) suggested that because the debate illustrates confusion between the role of scientists and that of the wider community in regulatory decision making it is important to reinforce the scientific results with non-scientific concerns to achieve an all-inclusive participatory approach on the continent. This is where decision making tools will help to address the issue of whether to implement GM crop cultivation in other Sub Saharan African Countries or not. Johnson et al. (2007) suggests two decision making tools that can help policy makers reach a consensus. Scientific risk assessment and Risk analysis methods will prove useful in regulatory decision making concerning the implementation of GM crops. In a nut shell Risk assessment forms the foundation for regulatory decisions on whether to authorize the environmental release of GM organisms (Keese et al. 2013). It is a structured and a reasoned approach that has the potential to assist in the identification or the discovery of a genetically modified organisms potential to cause adverse harm and to characterize the seriousness and the likelihood of potential harm (Keese et al. 2007). These methods will aid in assessing the risks that may accompany the implementation of GM crops. The result of the scientific risk assessment is not the decision whether or not to permit the cultivation of a GM crop and it is also not the only factor on which a decision is made. A decision will be made based on the amount of risk that is acceptable (the threshold value) if the crop is permitted to be cultivated, and, just as importantly, the risks of not permitting cultivation (Johnson et al. 2007). Acceptable risk cannot be determined solely on scientific based assessment although science is capable of predicting the likelihood of certain effects. Non-scientific criteria (risk analysis) must be included in the process of judging their acceptability so that results that are obtained outside of scientific assessments can be included in the decision making process (Johnson et al. 2007). This is what is referred to as public participation where communities that are both interested in and affected by the implementation of GM crops have the opportunity to voice their views and opinions. In Sub-Saharan Africa the main governmental agency in Burkina Faso responsible for the authorization of GMOs, l'Agence Nationale de Biosécurité, has provisions for involving the wider public in decision-making. The results of an all-inclusive decision making process has given the success of its insect resistant (*Bt*) cotton risk communication strategies in part to the involvement of varied stakeholders early in the adoption of the biosafety law, in the awareness-raising campaigns and also in undertaking confined field trials (Racovita et al. 2013). Scientific decision making tools such as environmental impact assessments, Life Cycle Assessments (LCA's) also known as "Cradle to the grave analysis" if implemented in Sub-Saharan African countries can help to evaluate the impacts of GM crops on its surrounding environment throughout its life cycle (Bennett et al. 2004).

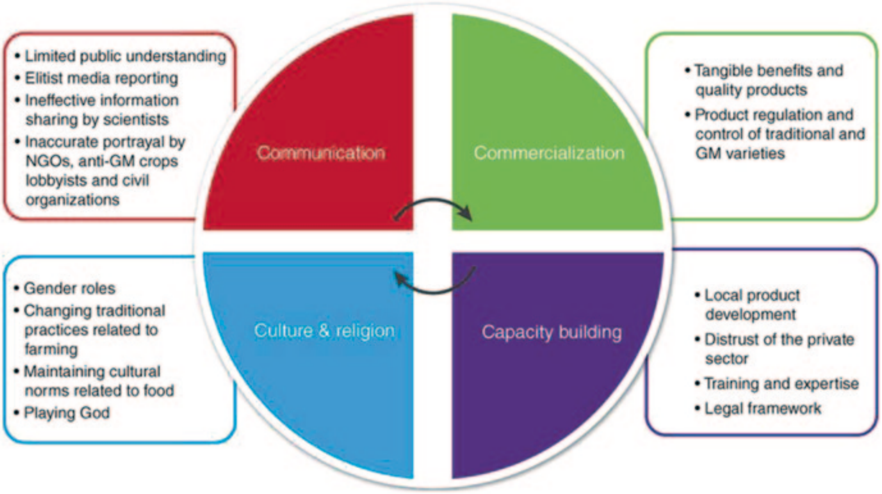

Fig. 2.3 Factors influencing the adoption and development of agbiotech in sub-Saharan Africa (Ezezika et al. 2012)

In brief Ezezika et al. (2012) spelt out the factors influencing agbiotech adoption and development in sub-Saharan Africa as in Fig. 2.3.

2.5 Progress of GM Crop Cultivation in SSA Countries

There are a myriad of concerns that surround the commercialization of GMOs in Sub Saharan African countries with the exception of South Africa and Burkina Faso. One of the concerns is that modern agricultural biotechnology or agbiotech, may have negative impacts on traditional seed systems such as seed selection, seed breeding, seed sharing and seed storage (Ezezika et al. 2012). Such impacts on these traditional seed systems can lead to a loss of indigenous varieties of seeds. This concern is one that has been of priority amongst NGO's and farmers associations. There are fears that the technology would lead to the (further) corporatization of agriculture, and that it is simply unethical to manipulate life in the laboratory. GM crops have been part of the agricultural landscape for more than 15 years and have now been adopted on more than 170 million hectares (ha) in both developed countries (48 %) and developing countries (52 %). On the basis of this substantial history and data spanning many years, the economic and environmental impacts of GM crops can now be summarized with some certainty, and the analysis indicates that, on balance, many benefits have accrued from the adoption of GM crops (Table 2.1). There are many ethical issues that are continuously being debated with many being resolved through institutional interventions. The future of agricultural productivity

Table 2.1 Status and trends in plant biotechnology in Africa (Brink et al. 1998)

Region	Country	Area of research
North Africa	Egypt	Genetic engineering of potatoes, maize and tomatoes
	Morocco	Micropropagation of forest trees, date palms
		Development of disease-free and stress tolerant plants
		Molecular biology of date palms and cereals
		Molecular markers
		Field tests for transgenic tomato
	Tunisia	Abiotic stress tolerance and disease resistance
		Genetic engineering of potatoes
		Tissue culture of date palms, *Prunus* rootstocks and citrus
		DNA markers for disease resistance
West Africa	Burkina Faso	Biological nitrogen fixation, production of legume inoculants, fermented foods, medicinal plants
	Cameroon	Plant tissue culture of *Theobroma cacao* (cocoa tree), *Hevea brasiliensis* (rubber tree), *Coffea arabica* (coffee tree), *Dioscorea spp* (yam) and *Xanthosoma mafutta* (cocoyam)
		Use of *in vitro* culture for propagation of banana, oil-palm, pineapple, cotton and tea
	Cote d'Ivoire	*In vitro* production of coconut palm (*Cocos nucifera*) and yam
		Virus-free micropropagation of egg-plant (*Solanum spp*)
		Production of rhizobial-based biofertilizers
	Gabon	Large-scale production of virus-free banana, plantain and cassava plantlets
	Ghana	Micropropagation of cassava, banana/plantain, yam, pineapple and cocoa
		Polymerase Chain Reaction (PCR) facility for virus diagnostics
	Nigeria	Micropropagation cassava, yam and banana, ginger
		Long term conservation of cassava, yam and banana, and medicinal plants
		Embryo rescue for yam
		Transformation and regeneration of cowpea, yam, cassava and Banana
		Genetic engineering of cowpea for virus and insect resistance
		Marker assisted selection of maize and cassava
		DNA fingerprinting of cassava, yams, banana, pests, and microbial pathogens
		Genome linkage maps for cowpeas, cassava, yams and banana
		Human resource development through group training, degree related training, fellowships and networking

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