Food Security and Biotechnology in Africa

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MODULE 3: PUBLIC RESPONSE TO THE RISE OF BIOTECHNOLOGY

Unit 4: Biotechnology and African Agriculture (4 hrs)

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Introduction

Africa has about 33 million small farms, representing 80% of all farms in the region. Majority of the farmers are small scale holders with two third of the farms below 2 hectares and 90%of all farms below 10 hectares (Alteri, 2009). Globally, the green revolution, while promoting crop yield proved to be unsustainable as it damaged the environment, caused drastic loss of biodiversity and associated traditional knowledge, favoured wealthier farmers and left many poor farmers deeper into debt. Of course, Africa did not benefit from this agricultural revolution and the new green revolution proposed for Africa through the multi-institutional Alliance for green Revolution in Africa (AGRA) appears destined to repeat the unsustainable record left by the fertilizer dependent miracle seeds, in Latin America and Asia by increasing dependency on foreign in-puts and patent-protected plant varieties which poor farmers cannot afford (Alteri, 2009). Most small farms practice low-resource agriculture based on the use of local resources, and make modest application of external in-puts. Most basic food crops are produced by small farmers with minimal use of fertilizers where it is used at all. Africa is a continent of about 900 million people, with about 200 million malnourished, and 33 million children go to bed daily hungry and malnourished (Thomson, 2008). Unfortunately, this is the region of the world with the fastest growing human population. Globally, some 6 million square miles of the earth are currently farmed. Without continuing yield increases, 15 million square miles could be needed by 2050, given current population projections (figure 1) (Kreuger, 2010).

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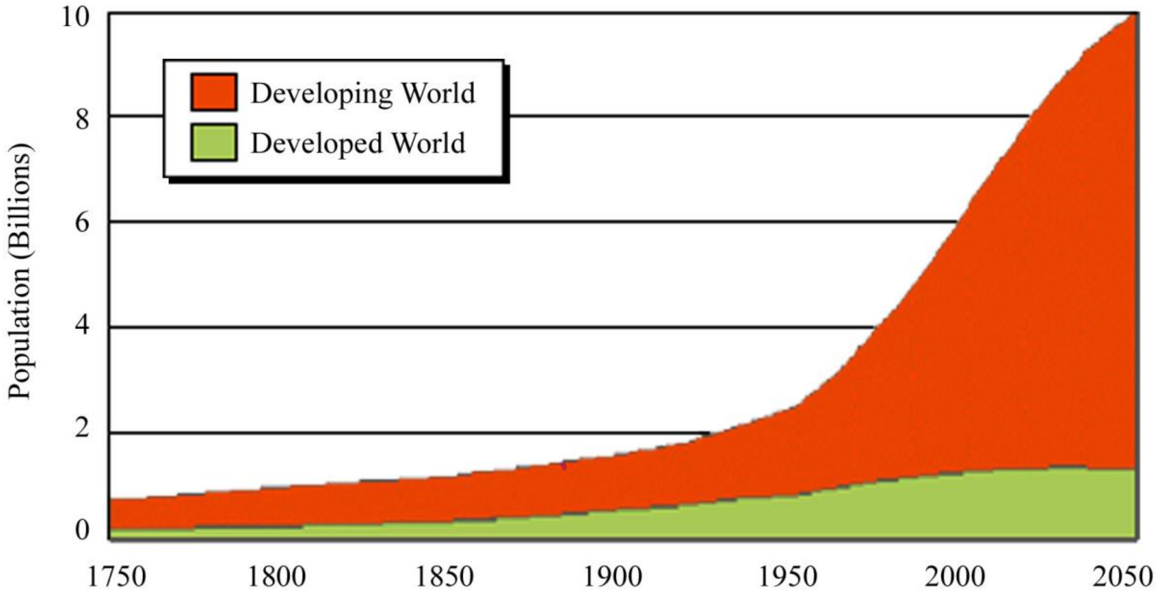

Figure 1. Population Projection to 2050 (From United Nations Population Division and Population Reference Bureau, 1993)

Moreover, Africa has the least crop yield per unit of cultivated land in the agricultural world (Wambugu, 1999). African agriculture has a unique set of features that differentiates it from Asian agriculture where the green revolution was a success including lack of dominant farming system, predominance of rain fed agriculture as opposed to irrigation, and prevalence of soils of poor fertility. There is a vast difference between a farmer growing just one to two crops and another growing a range of crops on just less than one hectare. Many developing countries are currently experiencing a nutrition transition, from rural to urban and sedentary, with diets containing more processed foods, sugars, fats and animal products (Pinstrup-Andersen, 2010). The result is a triple burden of malnutrition; a part of the population is undernourished, many are suffering from deficits of specific nutrients especially micronutrients while others are overweight. These call for urgent steps to address the issue of hunger and malnutrition on a sustainable basis and also to create conditions for meeting the increasing food demand arising from growing world population. Proposed means of addressing the above issues include giving the poor better access to income earning opportunities, creation of social safety nets, and targeted nutrition improvement measures.

Biotechnology as a solution to food security would however, place priority on staple food crops of lower income households such as sorghum, cassava, and banana. The food insecure households are subsistence farmers who are producing in risk prone environments at low productivity levels. To address their constraints would mean development of crops with traits to increase yields and reduce risks of crop failure from drought, pests and diseases. They would also include increasing production of more nutritious food crops. Initial interest of research and development on GM crops centred on export crops like cotton, maize and soy, while the food insecure farmers are concentrated in marginal areas vulnerable to drought and grow food crops such as sorghum.

Characteristics of African Agriculture and biotechnology development

African agriculture has a unique set of features that differentiates it from Asia or South America where the green revolution achieved a measure of success. These include absence of dominant farming system, predominance of rain-fed agriculture as opposed to irrigation and prevalence of soils of poor fertility. There is also a huge difference between farming practices on the fields of a farmer growing one or two different crops to another growing a range of crops on less than one hectare of land. The former will use varieties developed from highly inbred lines and adapted to relevant climate while the latter will grow many different crops that reduce risks of crop failures. Among the biggest challenges of African agriculture is the improvement of the nutrient status of farmlands, many of which are acidic, low in phosphorus and high in toxic aluminium ((Thomson, 2007). Without nutrient replacement, there cannot be agricultural sustainability. Due to poverty African farmers cannot afford inorganic fertilizers and thus contend with poor yields, about the lowest in the world per cultivated land (Wambugu, 1999).

The question of how to feed poor people in developing countries was addressed at a meeting organized under the auspices of International Food Policy Research Institute (IFPRI) in 2001. Among the interventions suggested was the use of modern biotechnology such as tissues culture, marker assisted breeding, biological control and genetic modification. However, caution should be observed to avoid the mistakes of green revolution. Two major lessons can be learnt from the challenges of green revolution. For one, ‘breakthrough’ technologies, brought in from the outside, can only have a limited success in Africa’s complex ecology.

African soils are generally unsuitable to intensive, monoculture production because of insufficient or excessive rains, high incidences of pests and diseases, and other factors. Secondly, the social, economic, and political conditions prevalent in Africa are as ill-suited as the ecology to ‘breakthrough’ technologies.

The World Bank estimates that half of its agriculture projects in Africa failed because the planning process did not take into consideration domestic infrastructure limitations (Kathen, 2002). Farmers in Sub-Saharan Africa lack access not only to markets, but also to infrastructure, research extension services, and all other forms of support. Policy-makers from developing countries have increasingly considered genetically modified (GM) crops as a potential tool for increasing agricultural productivity. Thus, Amongst the 29 countries cultivating GM crops worldwide, 19 are developing countries. Yet in SSA only two countries have approved the commercial cultivation of GM crops: Burkina Faso and South Africa. Nonetheless, the interest in GM crops appears to be growing, with up to six countries in SSA currently conducting confined field trials (CFTs) of GM varieties of locally-grown crops, including banana, cassava, cotton, cowpea, maize, sorghum, sweet potato and sugarcane. At least 12 countries are conducting research in contained facilities, and at least 23 are developing research and development (R&D) capacity in GM crops. According to Olembo et al., (2010), there are generally three categories of countries in biotechnology: (a) those that are generating and commercializing biotechnology products and services using third generation techniques of genetic engineering; (b) those that are engaged in third generation biotechnology R&D but have not developed products and/or processes yet; and (c) those that are engaged in second-generation biotechnology (mainly tissue culture). In the first category some African examples are Egypt, Zimbabwe and South Africa, while Kenya, Uganda and Ghana are examples of the second. Tanzania and Zambia are in the third category. Most of the biotechnology activities have focused on enhancing agricultural productivity.

In the 18 year period 1996 to 2013, millions of farmers in about 30 countries worldwide, adopted biotech crops at unprecedented rates. The most compelling and credible testimony to (the success of) biotech crops is that during the 18 year period 1996 to 2013, millions of farmers in about 30 countries worldwide, elected to make more than 100 million independent decisions to plant and replant an accumulated hectarage of more than 1.6 billion hectares. This is an area equivalent to more than 150% the size of the total land mass of the US or China which is an enormous area. There is one principal and overwhelming reason that underpins the trust and confidence of risk-averse farmers in biotechnology – biotech crops deliver substantial, and sustainable, socio-economic and environmental benefits. The comprehensive EU 2011 study conducted in Europe, confirmed that biotech crops are safe (ISAAA, 2013).

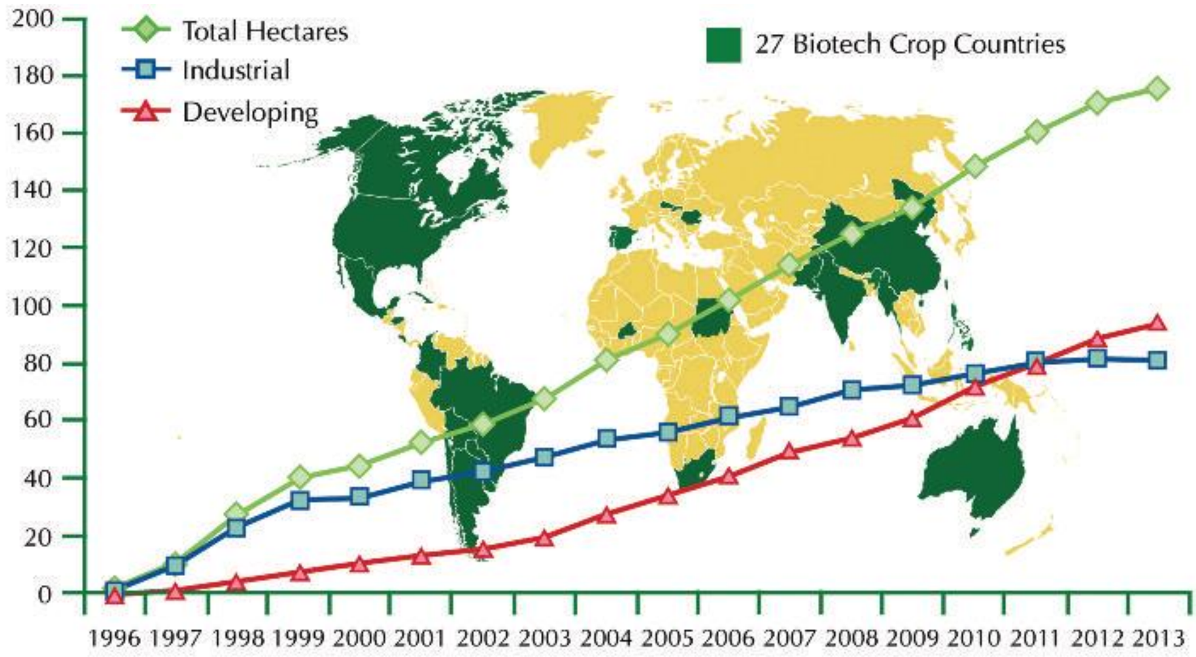

Figure 2: Global Area of Biotech Crops Million Hectares (1996-2013

A record 18 million farmers, in 27 countries, planted 175.2 million hectares (433 million acres) in 2013, a sustained increase of 3% or 5 million hectares (12 million acres) over 2012. Source: Clive James, 2013 James, Clive. 2013. Global Status of Commercialized Biotech/GM Crops: 2013. ISAAA Brief. No 46. ISAAA: Ithaca, NY.

South Africa and Burkina Faso are the only two African countries to have formally approved transgenic crops for commercial production. South Africa is the forerunner for agricultural biotechnology in Africa, having first established GM crop research by allowing Delta and Pine Land (D&PL) to introduce field trials of GM cotton in 1989 (Gouse, 2007). Nearly a decade later, with the enactment of the 1997 Genetically Modified Goods Act, South Africa formally initiated commercial production of genetically modified crops. South Africa has since approved various traits of genetically modified canola, maize, cotton, and soy for commercial production, but it has relied exclusively on the major private seed developers and agrochemical companies for research and development (ISAAA, 2011). Burkina Faso took a similar approach as South Africa, approving Monsanto's insect resistant, Bt cotton, for food, feed, processing, and planting (ISAAA, 2011). Burkina Faso stands as one of the most rapid adopters of biotechnology, with 260,000 hectares of Bt cotton cultivated in 2010 accounting for 65% of the nation's total cotton production (James, 2010). Similarly, Egypt approved an insect resistant maize variety developed by Monsanto for planting in 2008; but has yet to approve any transgenic crops for commercial production (ISAAA, 2011). The past two to three decades have witnessed increased investment in biotechnology (R&D by a number of African countries. Public research institutions and a few private companies in the region have established projects or programmes on biotechnology R&D. The nature of activities and levels of investment in the technology vary from one country to another and from one sector to another.

Many other African countries have begun to follow the model of South Africa, and now Burkina Faso, by relying on the capabilities of international corporations to perform the laboratory work, while attempting to focus national efforts towards conducting field trials and monitoring the efficacy of GM seed varieties in local climates. Currently, several multilateral organizations have begun to research GM crop technologies as part of very specific economic growth, development, poverty reduction and/ or food security agendas including but not limited to Forum for Agricultural Research in Africa (FARA), which plays major role in facilitating the information exchange across national, sub-regional, and private entities. Open Forum on Agricultural Biotechnology (OFAB), African Agricultural Technology Foundation (AATF) among others.

In Africa, benefits from GM technologies have already been demonstrated; in South Africa, under rain-fed conditions, Bt maize increased yield by 11% that translated into US$ 35/ha more revenue (James, 2008). In Burkina Faso, field trials on Bt cotton resulted in a two-thirds reduction in insecticide usage and a 15% higher yield, thus promoting farmers' and environmental health while promoting prosperity. More recently, the African Agricultural Technology Foundation initiated several public-private partnerships to enhance agricultural productivity in Africa, including the development of:

i. Bt cowpea for protection against the Maruca - pod borer with potential to increase yield from 0.3 to 2.5 kg/ha.

ii. Water Efficient Maize for Africa that is expected to provide about 30% more yield under moderate drought.

iii. Nitrogen- Use Efficient Rice for better performance under lower soil N.

iv. Bananas resistant to bacterial wilt in the Great Lakes region of East Africa, where the disease is causing up to 100% crop losses.

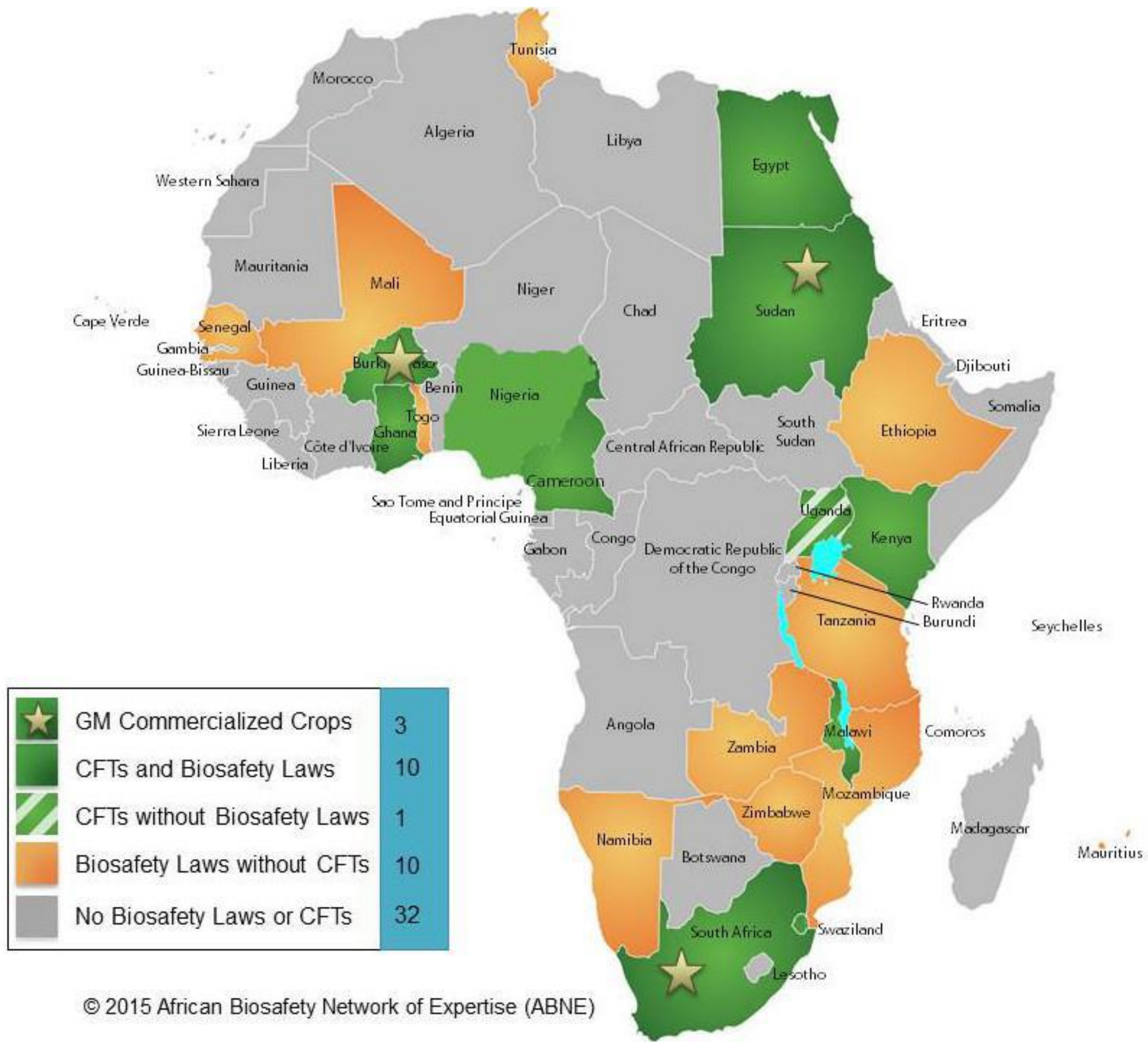

Figure 3: Status of Agricultural Biotechnology in Africa (2013

Do African Countries need Crop Biotechnology?

The components of techniques that constitute biotechnology if wisely applied can transform farming systems by reducing post-harvest loss, increasing crop resistance to drought, pathogens and poor soil fertility. Biotechnology and food security in Africa raises two basic questions; one, how to transfer biotechnology to African countries and strengthen their technological competence to acquire, assimilate, further develop, and effectively apply the technology for enhanced food production and, secondly, what policy and institutional frameworks should be instituted for technology accessibility by the rural poor farmers? Biotechnology can contribute in improving food insecurity issues in Africa. However, it should not be seen a panacea of all food insecurity matters in the continent as no technology has by itself an internal momentum to create food security for any society or region. It is how the technology is moulded and applied by the society that determines its usefulness. There are other issues such as access to food (whether it is affordable), can it be moved across regions effectively, equity at both national and international levels, and distribution of food nationally and globally. These issues impinge on food security but strictly speaking are not biotechnology related.

Concerning some of the perceived risks of the technology, there is no inherent goodness or badness of any technology as most have advantages and disadvantages. For example, people must have opposed the innovations of car and plane transports because of the danger inherent in their use. Same must have been the case with computers and cell phones. However, these technologies later proved to be worth the risks, but are not necessarily risk-free. The concerns should be how to maximize the benefits of the technology while minimizing the risks. Considering the educational levels of Africa states, much of the obstacles to the technology adoption have to do with ignorance and misinformation, key issues in the acceptance of any new technology. Having been left behind during the green revolution, African countries can ill-afford to miss gene revolution in agriculture which biotechnology is part of. The technology has transformed the agriculture and economies of USA, Canada and some countries in South America and Asia. Investments in infrastructures are *sine qua non* in the adoption of the technology especially in the area of monitoring and regulation of its applications.

The actors in the agricultural biotechnology Research and Development in African countries can be distinguished from their developed country counterparts where private corporations such as Monsanto are emerging as its drivers and therefore own and control biotechnology information. This of course is one area where apprehensions are rife with respect to the technology as it is feared that this will limit access due to the observance of intellectual property rights. In addition to technological growth and application as food security solutions, is the establishment of policies in the continent that will enhance food production and poverty alleviation. For instance, research focused on the nature of rural poverty in Africa (Jayne et al., 2003). Substantial research focused on the (1) nature of rural poverty in Africa have revealed some key themes such as; growth and distributional linkage effects between agriculture and the rest of the economy (2) how to stimulate development in areas considered disadvantaged by agro-ecological or geographic criteria (3) the relationship between the distribution of rural assets, economic growth, and poverty reduction and (4) recent advances in poverty mapping. In their studies the rate of agricultural growth is likely to be affected by the distribution of assets in the agricultural sector, particularly land. Thus, efforts should be made to review existing land allocation policies where they run counter to sustainable growth of agricultural production and application of scale dependent farming practices.

African countries are also expected to establish clear priorities in investments in biotechnology. Countries should identify specific areas or technology trajectories in which to invest to meet specific goals and respect of available skills. To address problems associated with financing, establishment of alliances with corporate bodies and even countries within regions is advised as a possible means of sustaining finance on research and development in biotechnology. Also, the role of intellectual property rights and their impacts on the acquisition, development and diffusion of the technology should be considered.

Summarily, Africa needs agricultural biotechnology. African countries should invest to develop the capacity to be able to implement agricultural biotechnology on the bases of specific needs. This will enable nations to choose what to practice and the time.

What will be the focus of African biotechnology adoption?

One of the major highlight of the International Food Policy Research Institute (IFPRI), conference in 2001 was how to feed the poor people in the developing countries (IFPRI, 2002) and entitled Sustainable Food Security for All by 2020. Among the interventions suggested was the use of modern biotechnology and in 2003, the United Nations Industrial Development Organization (UNIDO) convened a meeting in Nairobi to address the question of which biotechnological interventions were most suited to Africa. Two areas were chosen. Firstly, what interventions were readily available for adaptation to Africa, and secondly, what are the most pressing issues irrespective of how soluble in the future.

The list produced, not in any particular order include;

i. Insect resistant African maize varieties expressing the *Bacillus thuringiensis* (Bt) *cry genes* coding for insect specific toxins.

ii. Crops resistant to African viruses such as the maize streak virus (MSV) and the African cassava mosaic virus.

iii. Maize resistant to the parasitic weed Striga

iv. Decreased level of mycotoxins in maize, which may be possible due to the diminished post-harvest fungal infection in Bt maize varieties.

v. Drought tolerant crops (Thomson, 2008).

Given the lack of practical government commitment to science and development in Africa, scientists in the region have turned to external funding sources to keep their hope and dreams alive. Consequently, agricultural research and development project priorities are often not determined by the African countries themselves but by the funding agencies. Even in countries with local funding like South Africa, scientists in most cases need to supplement their funding with external income and frequently bow to the agendas of the funding bodies.

Current Biotechnology Projects in the African Continent

i. African Agricultural Technology Foundation (AATF): Banana and cowpea improvements, control of Striga, and drought tolerance in maize. The water efficient maize for Africa (WEMA), aims to produce drought tolerance maize through a combination of conventional breeding, marker assisted breeding and GM technology funded by Bill and Melinda Gates and H. G. Buffet Foundations.

ii. The Africa Bio-fortified Sorghum (ABS): The project is aimed to develop a nutritionally fortified/ enhanced GM sorghum with increased levels of essential nutrients especially vitamin A, Lysine, iron and zinc. The project is funded by the Bill and Melinda Gates foundation.

iii. The Bt Potato Project: The project is meant to develop insect-resistant potatoes for up take by small scale farmers. It is funded by USAID.

There are other collaborative programmes like the European Union framework collaborative programmes undertaken by African scientists with their EU collaborators.

Characteristics of GM crops and factors enhancing their adoption

Genetic engineering, a branch of biotechnology differs from conventional methods of genetic modification in some major ways; it implements direct modification in the genome of an organism; genetic engineering introduces one or more well characterized genes into a plant species and can introduce genes from any species into another organism. However, conventional breeding methods of genetic modification used to create new species (artificial selection, forced interspecific transfer, random mutagenesis, marker assisted selection etc. introduce many uncharacterized genes into the same species.

The process of GE entails potential risks to consumers of the product either as a result of the products (proteins) that the new genes will code for or some pleiotrophic effects of the newly introduced genes on other genes in the plant. Thus, the products of GE are subjected to regulatory and risk assessment regimens. In the 1960s, the biologist Rachel Carson, brought the detrimental environmental and human health impacts from overuse or misuse of insecticides to the public purview. As an escape from this detrimental health and environmental effects of agricultural chemicals, crop biotechnology was developed with the view of possibly addressing these impacts. Thus, most of the engineered crops were designed to reduce reliance on sprays of broad spectrum insecticides for pest control in agricultural crops (Ronald, 2011).

Corn and cotton have been engineered to produce proteins from the soil bacterium, *Bacillus thuringiensis* that kills some key caterpillars beetle pest of these crops. Bt toxins cause little or no harm to most non target organisms including beneficial insects, wild life and people. The outcome will be improved yield from the crops and income to the farmer, reduced application of insecticides and health benefits to the sprayer. Planting of Bt cops has also supported another important goal of sustainable agriculture, increased biological diversity which is seriously affected by chemical insecticides. Moreover, it has been possible to delay resistance to the Bt toxin by gene stacking, an improvement in the pesticide use with respect to the ease of pesticide resistance.

Weeds are major limitations of crop production worldwide as they compete for nutrients and space with planted crops. Herbicide sprays have been an age long practice for weed control. Many of the herbicides used in the past 50 years are to graded levels, toxic to animals and man. A modern herbicide (type iv) is typified by glyphosate a very low acute toxicity chemical that is non-carcinogenic and breaks down very fast in the environment. Some crops via GE have been engineered to be tolerant to glyphosate. Growers of glyphosate tolerant crops can spray glyphosate to control weeds without harming their crops.

Viral resistant crops

Although Bt and herbicide tolerant crops constitute the greater acreage of genetically engineered crops, other genetically engineered crops have been commercialized and proved to be effective tools for sustainable agriculture. Some fits have been recorded in this area especially in the control of tobacco mosaic virus and the papaya ring spot virus.

A review of works on genetically engineered crops currently in the market showed that such crops have contributed significantly in enhancing global agricultural sustainability. The review showed such benefits as massive reduction in insecticidal use with huge environmental benefits, (Huang et al., 2005), improved soil quality and reduced erosion (Committee on the Impact of Biotechnology on Farm level Economics and Sustainability and National Research Council, 2010), Prevention of the destruction of Hawaiian papaya industry (Ronald, 2011), enhanced health benefits to farmers and families as a result of reduced exposure to harsh chemicals (Huang et al., 2002), economic benefits to local communities Qiam et al., 2010), enhanced biodiversity of beneficial insects (Thomson, 2010), reduction in the number of pest outbreaks on neighbouring farms growing non genetically modified crops (Ronald, 2011), and increased profit to farmers (Tabashnik, 2010). Other attractive traits include crops with better nitrogen utilization efficiency that may not need nitrogen fertilizers and thus will reduce eutrification/ pollution of water bodies, crops tolerance to environmental stresses, enhancement of nutritional qualities of foods as in fortification with iron, zinc and vitamin A (Ronald, 2011), and enhanced post-harvest storage of crops.

Constraints to GM Adoption in Developing Countries

The break between public and private sector plant improvement efforts came with the advent of biotechnology, especially genetic engineering. The proprietary protection offered for the artificially constructed genes and the genetically modified plants provided the incentive for private sector entry and eventual takeover of researches and R &D on genetic engineering. The large multinational agro-chemical companies were the earliest investors on foreseeing a looming decline in the profits from agrochemicals. This they did by first acquiring the existing seed companies first in the developed countries and later, in the developing countries. This is the genesis of how the big corporations later became the leaders in biotechnology and the consequent allegation against the technology on the ground that the big companies that control the technology are seeking control of world food system.

Thus, developing and application of the technology first took root in the developed world while the developing countries are yet to catch up, with the exception of China. Moreover, there are some ethical concerns relating to the the proprietary nature of most of the key enabling crop biotechnologies used today. To this end National Science Academies of several countries have requested the private corporations and research institutions to make arrangements to share genetic engineering technology with responsible scientists for alleviating hunger and enhancing food security in developing countries. Currently, that technology is now held under strict patents and licensing agreements which do not favour the citizens of the developing countries. Other non-technical constraints include potential effects of the technology on the environment and human health, the social implication of playing God as some people consider the methodology involved in the innovation as unnatural, Fear of reducing food variety as the technology is accused of non-sensitivity to orphan crops and thus food sovereignty. In addition, developing countries have peculiar constraints on the acquisition and use of crop biotechnology. These include; traditionally, the supply of improved seeds to smallholder farmers in developing countries was dominated by the public sector, the GM crop development and commercialization are driven by the private sector—mostly rich country multinationals. The patenting of GM products is a big task for the developing countries as they a limited in their ability to carry out similar research and will have to pay any price attached to GM products. Secondly, Cost of the technology; just as this is a determinant of the rate of adoption it also is a constraint in that the higher the cost, the less capable most poor rural farmers would be in adopting the technology. Thirdly, High costs of compliance with biosafety regulation may deter small firms or institutions from developing and commercializing GM products in developing countries. Defficiencies in high level manpower is also a constraint to GM technologies in the developing countries. Some GM crops require special care and training different from the traditional approaches common in developing countries.

References and Further Reading.

Alteri,M.A (2009) Small farms, and food Sovereignty. Agroecology Monthly Review, July-August. Pp 102-113

Tabashnik, B.E (2010). Communal benefits of transgenic corn. Science 330: 189-190

Huang, J, Hu, R, Rozelle, S, and Pray, C (2005) Insect resistant GM rice in farmers' fields: Assessing productivity and health effects in Chnia. Science 308: 688-690.

Huang, J, Rozelle, s, Pray, C, Wang, Q (2002). Plant biotechnology in China. Science 295: 674-676

Ronald, P (2011). Plant genetics, sustainable agriculture and food security. Genetics 188:11-20.

Jahye, T.S, Yamano T, Webera, M.T , Tschirleya, D , Benfica, R , Chapoto, A, and Ballard Zulu, B (2003) Smallholder income and land distribution in Africa: implications for poverty reduction strategies Food policy 28(3): 253-375

James, C (2008). Global status of Commercialized Biotech /GM Crops. ISAAA Brief NO 39. ISAAA, Ithaca, NY

ISAAA Brief 46, "Global Status of Commercialized Biotech/GM Crops: 2013

de Kathen, A (2002) Pre-print version of report for the Federal Environmental Agency (Germany).

Pinstrup-Andersen, P (2009) Food security: definition and measurement. Food security 1 pp. 5-7.

Kreuger, R.W (2001) The Public Debate on Agrobiotechnology: A Biotech Company's Perspective. AgBioForum . Volume 4, Number 3&4 . PP 209-220

Wambugu, F.M (1999) Why Africa needs agricultural biotechnology, Nature 400:15-16 (doi; 10. 1038/21771)

Thomson, J (2008) The role of biotechnology for agricultural sustainability in Africa. Phil. Trns. R. Soc B 363: 905-913.

McBride, W. D. and El-Osta. H.S (2002).Impacts of the Adoption of Genetically Engineered Crops on Farm Financial Performance. Journal of Agricultural and Applied Economics **34**: 175-191

Makoni, N & Mohamed-Katerere, J AFRICA ENVIRONMENT OUTLOOK 2 300-330

Ruane, J. & Sonnino, A. (1011). Agricultural biotechnologies in developing countries and their possible contribution to food security. Journal of Biotechnology 156: 356– 363

Pavone, V., Goven, J. & Guarino R. (2011) From risk assessment to in-context trajectory evaluation - GMOs and their social implications. Environmental Sciences Europe, 23:3

Wieczorek, A (2003) Use of Biotechnology in Agriculture— Benefits and Risks Biotechnology CTAHR — May 2003. 1-6