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Agricultural Biotechnology the Panacea for Food Security in Sub-Saharan Africa

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Abstract: Africa is lagging behind in terms of agricultural development and food security in spite of her rich human and natural resources. Crop and animal improvement is still done using the traditional breeding methods. Emphasis need to be placed on the use of agricultural biotechnology in combination with the conventional breeding methods to give a boost to agricultural growth in sub Saharan Africa. This will relate to increased crop and animal yield, resistance to pests and diseases as well as abiotic stress tolerance in crops. Adequate funding by African governments as well as capacity building will be required to achieve this boost. The role of public-private partnership in this regard cannot be overemphasized. The use of plant tissue culture and micropropagation methods for the regeneration of transformed plants as well as the use of molecular breeding and marker assisted selection for better selection and genetic diversity studies have over the years given a boost to crop and animal improvement through agricultural biotechnology. The use of this modern technology should be encouraged for improvement in the livelihood of citizens and enhanced food security. Adequate biosafety laws to regulate agricultural biotechnology must also be in place so that technology will assist in the production of food that is safe and nutritious, while ensuring a continuous improvement in the efficiency of food production.

Key words: Genetic engineering % Marker assisted selection % Micropropagation % Sustainable agriculture % Tissue culture

INTRODUCTION

The world's population keeps on increasing at a rate, which may not be matched by food production efficiency. In sub-Saharan Africa, agriculture still remains at the subsistence level, often with poor planting materials being used by farmers. Africa is blessed with rich human and natural resources yet many individuals live below the poverty line. During the last decades there has been a gradual decline in the number of hungry people, which was made possible by the Green Revolution in which technological advancements doubled the grain yields in large parts of Asia and Latin America entailing improved food availability for poor consumers at affordable prices. The technological change introduced by the Green Revolution has however discriminated against small, sustenance-level production, contributing to the loss of food self-sufficiency and agro-biodiversity at the local level among many areas of Asia, Latin America and Africa [1]. The benefits of Green Revolution has not been sustained, as hunger and poverty remain pervasive in the early twenty-first century in developing countries. Despite the huge gains of the Green Revolution, it caused environmental and socio-economic problems. Emphasis was placed on export cash crops and monoculture farming systems, which led to the erosion of genetic resources in food systems.

A prior, biotechnology, one of many tools of agricultural research and development, could contribute to food security by helping to promote sustainable agriculture centered on smallholder farmers in developing countries. Biotechnology is the use/manipulation of biological systems, processes or organisms, for the benefit of mankind. Application of biotechnological methodologies has made it possible to manipulate genes for almost any character, resulting in the production of desired traits in whatsoever host we desire. Thus, biotechnology could boost global crop output in the future while promoting environmentally friendly agricultural production patterns [2]. It offers promising

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potentials in sustaining food security in sub-Saharan Africa and the world in general. It can enable farmers to obtain increased crop yield, it is applicable to large-scale micro-propagation of economic crops such as oil palm, yams, cassava, plantain and banana, in addition to increased milk production in cows. Biotechnological knowledge can help in alleviating crop yield loss through production of crops resistant to pests, viruses, insects and diseases. Agricultural biotechnology deals with the improvement of crops and livestock using biotechnological means. It encompasses a number of tools and elements of conventional breeding techniques and derives support from allied disciplines such as plant physiology, biochemistry, molecular biology, microbiology, molecular genetics and bioinformatics.

This article describes the major biotechnological tools relevant to agricultural biotechnology and the way forward in its implementation in Africa. Besides the conventional plant breeding, there are three other biotechnological tools that are essential for the success of agricultural biotechnology.

Conventional Plant Breeding: Plant breeders search for new genetic variation to crop species through intra-specific gene transfer giving rise to the modern cultivated varieties we have today. Plant breeding deals with the selection of plants with desired qualities after sexual exchange of genes by cross-fertilization between two parents. The selection for features such as faster growth, higher yield, pest and disease resistance, larger seeds, or sweeter fruits has dramatically changed domesticated plant species compared to their wild relatives. Thousands of years ago, the corn cobs farmers harvested in North and South America were smaller than one's little finger. Today, there are hundreds of varieties of corn, some of which produce cobs as long as one's forearm [3]. Prehistoric selection of visible phenotypes that facilitated harvest and increased productivity led to the domestication of the first crop varieties [4]. When the science of plant breeding was further developed in the 20th century, plant breeders understood better how to select superior plants and breed them to create new and improved varieties of different crops [3].

The plant breeding paradigm has been enormously successful on a global scale, with such examples as the development of hybrid maize (*Zea mays*) [5], the introduction of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) varieties during the Green Revolution [6] and most recently the commercialization of transgenic crops [7]. Conventional plant breeding has been the method used to develop new varieties of crops. However, it can no longer sustain the global demand for adequate food supply especially with the increasing population and decline in agricultural resources such as land and water. Hence, new crop improvement technologies need to be developed and utilized. Furthermore, conventional plant breeding has some limitations. It requires sexual transfer of genes between two plants, thereby limiting new traits to that already present in that species. It is also impossible to transfer only those traits that are targeted by plant breeders. When plants are crossed, many traits that may not be useful are transferred along with the trait of interest including traits with undesirable effects on yield potential. Therefore, Agricultural biotechnology essentially, is an option for breeders to overcome these problems.

Plant Tissue Culture and Micropropagation: Much of the progress with improvement of crop plants via biotechnology relies on the ability to introduce DNA into single cells and then, generate completely fertile plants from those single modified cells by a process of regeneration. Plant tissue culture along with molecular genetics is a core technology for plant genetic transformation. It deals with the *in-vitro* culture of sterilized plant seeds, cells, tissues and/or organs, on media under aseptic conditions.

In order to understand the principles involved in tissue culture, two basic concepts must be taken into consideration. Plasticity permits plants to alter their metabolism; growth and development to best suit their environment. When plant cells and tissues are cultured *in vitro* they generally exhibit a very high degree of plasticity, which permits one type of tissue or organ to be initiated from another type. In this way, whole plants can be subsequently regenerated [8]. The ability of plant tissues or organs to regenerate into whole plants, totipotency was first demonstrated by Gottlieb Haberlandt [9] when he reported the first successful plant tissue culture of isolated single palisade cells from leaves in Knop's salt solution enriched with sucrose. He visualized the idea of growing plant cells in artificial medium with the hope of rejuvenating a quiescent cell and triggering it into division and growth, to form a tissue and eventually, regenerate an entire plant. Totipotency is the ability of all plant cells given the correct stimuli, to express the total genetic potential of the parent plant. Plant tissue culture has generated intense interest among molecular

biologists, plant breeders and commercial horticulturists as it has assisted in reducing the length of breeding programs and difficult to cultivate plants can be successfully grown *in vitro*.

Through organogenesis and somatic embryogenesis, large-scale production of crops within a short period of time is now possible. Organogenesis involves the development of shoots and roots when plant cells or tissues are cultured in a medium containing adequate concentrations of an auxin and a cytokinin using various culture methods while somatic embryogenesis leads to the production of embryoids from somatic cells or tissues that resemble zygotic embryos. It is often used for *in vitro* regeneration in the production of transgenic plants. It is necessary and essential for gene transfer studies as somatic embryos originate from single cells. A wide range of plant species are amenable to embryogenic callus initiation and regeneration through somatic embryos while some are recalcitrant. Somatic embryogenesis has been reported using different explants in legumes and underutilized crop species such as peanut *Arachis hypogea* L. [10], *Mucuna* [11]; *Pisum sativum* [12]; pigeon pea (*Cajanus cajan*) [13]. Plant culture media generally consist of several inorganic salts in small quantities, some organic supplements such as vitamins and phytohormones/growth hormones, organic constituents such as sucrose as carbon source and a solidifying agent. One of the most widely used media is the medium developed by Toshio Murashige and Folke Skoog [14]. The Murashige and Skoog medium is so well-known to the scientific community that it is often abbreviated simply as the MS medium. There are several types of culture methods used in plant tissue culture depending on the part of the utilized explant.

Protoplast Culture: Protoplasts are plant cells with the cell wall removed. The cell wall can be removed by either enzymatic isolation or mechanical isolation. Enzymatic isolation is the preferred method because it does not disturb the structure of the cell. Cocking [15] isolated protoplast of plant tissues for the first time by using the cell wall degrading enzymes; cellulase, hemicellulase, pectinase and protease obtained from the saprophytic fungus *Trichoderma viride.* The removal of the cell wall permits fusion of protoplasts of similar or different species with the subsequent regeneration into entire plants. This somatic fusion of two vegetative cells gives rise to hybrids. Protoplasts are good explants for transformation by several methods. Totipotency has been exploited by scientist over the years in regenerating plants from protoplast in both monocots and dicots. It is also possible to transfer foreign genes into plants using the protoplast as the starting material. Plants regenerated from a transformed protoplast would therefore contain the foreign gene of interest.

Embryo Culture: Embryo culture is the sterile isolation and growth of immature and mature embryo *in vitro* using sterile aseptic techniques in order to obtain a viable plant. Embryo culture is used when there is incompatibility after hybridization and also for breaking dormancy of recalcitrant seeds. Two types of embryo culture are used in tissue culture; immature embryo culture/embryo rescue and mature embryo culture.

Embryo rescue involves the culture of immature embryos of plants in a special medium to prevent abortion of the young embryo and to support its germination. When crosses are made between different species of similar or different genera, it is relatively difficult to obtain viable plants. In immature embryo culture, the immature embryos are rescued from wild crosses which otherwise would abort. This technique has been very useful in plant breeding. The underlying principle of embryo rescue is the aseptic isolation of embryo and its transfer to a suitable artificial growth medium for development under suitable culture conditions into plantlets. The development of a new rice plant type for West Africa (NERICA-New Rice for Africa) was a result of wide crosses between the Asian *Oryza sativa* and the African rice *Oryza glaberrima* . It employs embryo rescue in the initial breeding and in the successive back crossing work followed by anther culture to stabilize the breeding lines. The new plants had combined yield traits of the sativa parent with local adaptation traits from *glaberrima*, [16]. Mature embryo culture involves the culture of embryos obtained from mature seeds and it is carried out when embryos remain dormant for a long period of time or to prevent inhibition of seed germination. Excision of embryos from the testa and transfer to culture media may circumvent seed dormancy.

Anther Culture: Anther culture has come a long way in enhancing plant breeding for crop improvement. This tissue culture method is used to develop improved varieties within a short time. It is routinely used in double haploid production of several crops; barley, brassica, wheat, rice and oats [17]. Pollen within an anther contains haploid cells which spontaneously double (diploid) during culture. During microsporogenesis, tetrads of microspores are produced from a single mother cell. The

haploid plants can be treated with colchicine to double the chromosome numbers, forming double haploids which attain homozygosity after one generation. Hence, homozygous lines are obtained via anther culture within a short time rather than several years required in a conventional breeding program. In China, a large number of rice varieties have been developed through anther culture and released for cultivation over several thousand hectares [18]. This technique could be utilized for the improvement of African rice in swampy regions where rice is grown in sub-Saharan Africa.

Meristem Tip Culture: Meristem tip culture is the culture of apical meristems, which are capable of active cell division and differentiation into specialized and permanent tissues such as shoots and roots. It is the method used in micropropagation for the production of disease free plants, which is essential for safe germplasm transfer between countries. Meristem-tip culture takes advantage of the fact that some viruses are unable to colonize this region because of inhibition of replication and restriction of their movement [19]. Also, the absence of vascular differentiation in the meristem impairs interculture movement of viruses and being a centre of intense metabolic activity, the meristem which represents a virus free explant is therefore, a method par excellence for production of certain crop plants and ornamental species that are free of pathogens. Plants derived from meristem tip culture are characterized by chromosome stability, all being diploid and exhibiting phenotypic factors of the mother plant from which they were derived [20]. The meristem has the capacity of producing a complete plant *in vivo* and *in vitro.* The totipotency of its undifferentiated cells is the basis of the meristem tip culture technique [21]. Shoot apical meristem culture as a technique has seen a widespread practical application in horticulture and agriculture, in the large scale production of plantlets of economic value and in the recovery of virus free plants.

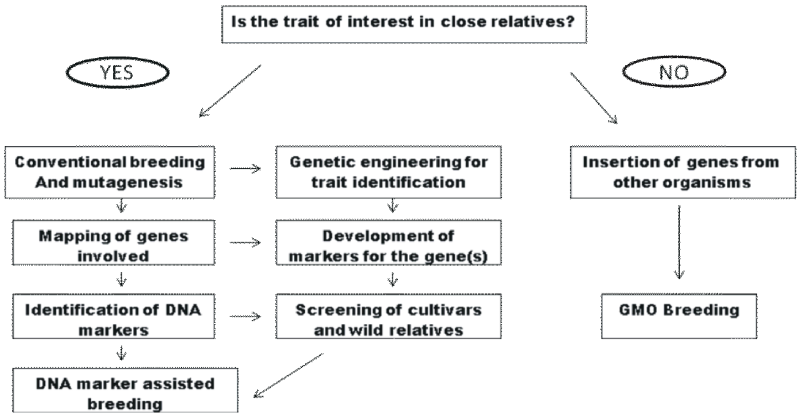
Micropropagation: Micropropagation is the method used in plant tissue culture for asexual propagation of plants for *in vitro* germplasm conservation and crop improvement. It is used for the production of disease-free, high quality planting material and for rapid production of many uniform plants. Meristem and shoot tip culture are the methods of choice for micropropagation. Meristems are placed in a special medium and treated with plant growth regulators to produce many clones of plantlets. Since the meristem divides faster than disease-causing virus being a region of actively dividing cells, clean materials are propagated and hundreds of uniform plantlets are produced in a short time. Through micropropagation, it is now possible to provide clean and uniform planting materials in plantations such as oil palm, plantain, pine, banana, rubber tree; field crops such as eggplant, pineapple, tomato; root crops such as cassava, yam, sweet potato; and many ornamental plants such as orchids.

The Micropropagation Techniques Are Preferred over the Conventional Asexual Propagation Methods for Several Reasons:

- Only a small amount of tissue is required to regenerate millions of clonal plants in a year.
- Micropropagation is also used as a method to develop resistance in many species.
- In vitro stock can be quickly proliferated as it is season independent.
- Long-term storage of valuable germplasm is made possible.

The ability of plant tissues to regenerate a new plant is an important requisite in the development of improved crops through agricultural biotechnology. Thus, the use of plant tissue culture to enable the development of genetically modified crops shows its importance in our lives.

Molecular Breeding and Marker Assisted Selection (MAS): Conventional plant breeding methods involve crosses between two parents usually a cultivated variety and a wide relative, which lead to the production of F1 hybrids. While traditional breeding approaches have worked well, they can be very time consuming and sometimes inefficient. Each plant has thousands of genes, so crossing two plants results in many combinations. Several backcrosses need to be made sometimes up to the 12^{th} generation to get the desired homozygosity. Phenotypic traits targeted by plant breeders could be caused by a single gene but some complex traits in plants and animals are controlled by polygenes (two or more genes). These traits have a polygenic mode of inheritance. Polygenic traits in plants include crop yield, starch content, amongst others. Traditionally, plant breeders have selected plants based on their visible measurable traits, the phenotype which is usually influenced by the environment. It is costly not only in the development itself, but also for the economy, as farmers suffer crop



Source: DANIDA, 2002 [29].
Fig 1: Molecular plant breeding methods

losses due to environmental factors. With advances in recombinant DNA technology, scientists can now precisely identify through marker technology some of the individual genes responsible for producing a particular trait. Plant breeders now use molecular plant breeding methods to circumvent the limitations of conventional plant breeding earlier mentioned. The selection using molecular markers can be enhanced and the efficiency of the molecular marker will be higher if the markers are closely linked to the gene controlling quantitative and qualitative characters [22].

Molecular breeding involves the use of molecular markers to identify the location of useful genes in plant and animal genomes (Fig 1). The markers are located near the DNA sequence of the desired gene. Since the markers and the genes are close together on the same chromosome, they become linked and transferred together as each generation of plants is produced. This genetic linkage aids scientists to predict whether a plant will have the desired gene. If researchers can find the marker for the gene, it means the gene itself is present. Novel genetic tools make use of several molecular marker techniques, which allows linkage map of crops to be established [23, 24]. Molecular markers are being used for crop improvement to achieve different objectives such as measuring genetic diversity among genotypes, genetic diagnostics, characterization of transformants, study of genome organization and phylogenic analysis. These markers are based on naturally occurring polymorphism in DNA sequences [25]. Molecular markers and more recently, high throughput genome sequencing efforts, have dramatically increased knowledge of and ability to characterize genetic diversity in the germplasm pool for essentially any crop species [26]. MAS can be used to manipulate both quantitative and qualitative traits and it has become a promising and potent approach for integrating biotechnology with conventional and traditional breeding. Plant breeders have focused their interest on the use of molecular markers on certain basic issues; resistance breeding, improvement of qualitative characters, developing markers for hybrid vigor in crops such as maize, sorghum, rice, cotton and several vegetables, as well as molecular markers for abiotic resistance [27]. MAS have been used for selection for salt tolerance in rice (*Oryza sativa* L) [28]. It is being used in the efficient introgression of important genes into rice such as bacterial blight resistance, increased beta carotene content which led to the production of Golden Rice and submergence tolerance to name a few. It is currently being done in maize.

Genetic Engineering and Genetically Modified (GM) Foods: With the advent of recombinant DNA technology in the early 1970's, it has now become possible to transfer desirable genes from one species or genera to another, which was not possible with the traditional plant breeding process. Genetic engineering is the process by which the genetic makeup of an organism can be altered using "recombinant DNA technology." Not all genetic engineering techniques involve inserting DNA from other organisms. Plants may also be modified by removing or switching off particular genes. Plant breeders look for genetic diversity in crop germplasm to select parents for breeding, hence the establishment of gene banks for the conservation of genetic resources of plants and animals. In cases where the desirable genes do not occur in a germplasm, the need for genetic engineering arises. It is used only when other approaches have been exhausted.

The era of plant genetic engineering began in the early 1980s with reports of the production of transgenic plants using the natural genetic engineer *Agrobacterium* [30]. Genetic engineering requires the successful completion of some basic steps; nucleic acid extraction, gene cloning, gene design and packaging, genetic transformation, detection of the inserted genes and backcrossing breeding if required.

The term GM food (genetically modified foods) is most commonly used to refer to crop plants created for human or animal consumption using the molecular biology techniques such as the recombinant DNA technology. These plants have been altered in the laboratories using tools of molecular biology for several reasons which include enhanced growth and nutritional status, pest and disease resistance or tolerance to abiotic stresses such as drought or high salinity. The current methods in use are vector mediated gene transfer methods; agrobacterium transformation and virus mediated transformation or direct gene transfer methods such as biolistics /particle bombardment, microinjection and electroporation. Plant geneticists can isolate a gene responsible for drought tolerance and insert that gene into a different plant. The new genetically-modified plant will gain drought tolerance as well. This is presently being tried for drought tolerant maize in northern Nigeria. Not only can genes be transferred from one plant to another, but genes from non-plant organisms can also be used. The first commercially grown genetically modified whole food crop *Flavr Savr tomato*, was made more resistant to rotting by Californian Company Calgene in the United States. The bioengineered tomato, offers many benefits, including a garden fresh taste all year round. It was genetically engineered to soften slowly so that the fruit can remain on the plant until ripe, hence it stays fresh without rotting and deliver natural flavor all year [31]. The United States Food and Drug Administration (FDA) approved it in May 1994.

C Categories of Genetically Modified/Transgenic Crops

First-generation Transgenic Crops: This involves improvement in agronomic traits, such as better resistance to pests and diseases. The use of *Bt* genes in maize and other crops is a very good example of First-generation GM crops. *Bt* gene was isolated from *Bacillus thuringiensis*, a naturally occurring bacterium that produces toxic proteins to larvae of some lepidoptera and coleoptera insect species. *Bt* crystal protein genes have been transferred into maize, enabling it to produce its own pesticides against insects such as the European corn borer. Therefore, *Bt* is a pest-control agent that can be used as a substitute for chemical insecticides. *Bt* rice has been field tested extensively in China and other countries [32]. South Africa has developed Bt maize and Cotton which has enhanced the productivity of farmers and hence, better income.

Second-Generation Transgenic Crops: The second-generation GM technologies that are ongoing include product quality improvements for nutrition and industrial purposes. Examples are oilseeds with improved fatty acid profiles; high-amylose maize; staple foods with enhanced contents of essential amino acids, minerals and vitamins; and GM functional foods with diverse health benefits [33; 34]. Golden Rice is a current example of GM biofortified crop, which contains significant amounts of provitamin A. It could become commercially available in some Asian countries by 2012 [35]. Biofortification of rice with vitamin A was undertaken to reduce vitamin A deficiency in children. Widespread production and consumption of biofortified staple crops could reduce micronutrient deficiencies, improve health outcomes and provide economic benefits [36].

Third-Generation Transgenic Crops: These transgenic crops are designed to produce special substances for pharmaceutical or industrial purposes [37]. The use of plants to express proteins can be more practical, safe and economical compared to other biological systems. The production of these compounds in plants is called molecular pharming. Crops are used to produce either pharmaceuticals such as monoclonal antibodies and vaccines or industrial products such as enzymes and biodegradable plastics [38]. The first protein produced in plants was human serum albumin in 1990 in transgenic tobacco and potato plants. Later two plant derived pharmaceuticals were produced in Cuba and US. Transgenic tobacco has recently been used in Cuba for the commercial production of a recombinant antibody against hepatitis B, while in maize it has been used for the commercial production of recombinant avidin, b-glucuronidase and trypsin by ProdiGene Inc USA [39]. Demand for specific pharmaceuticals is very high especially in developing countries. Recombinant hepatitis B vaccine from genetically-modified yeast, for instance, cannot be made in sufficient quantities and at a low enough cost to meet the current demands. The possibility of large-scale production in transgenic plants could offer one of the few practical solutions to overcome these dilemmas.

Table 1: Plant-derived pharmaceuticals for the treatment of human diseases that are in the pipeline for commercialization.

Product	Class	Indication	Crop
Human intrinsic factor	Dietary	Vitamin B12 deficiency	Transgenic *Arabidopsis*
Lactoferrin	Dietary	Gastrointestinal infection	Transgenic maize
Norwalk virus capsid protein	Vaccine	Norwalk virus infection	Transgenic potato
Rabies glycoprotein	Vaccine	Rabies	Viral vectors in spinach
Cyanoverin-N	Microbicide	HIV	Transgenic tobacco
Insulin	Hormone	Diabetes	Transgenic safflower
Lysozyme, Lactoferrin, Human serum albumin	Dietary	Diarrhea	Transgenic rice
Various single-chain Fv antibody fragments	Antibody	Non-Hodgkin's lymphoma	Viral vectors in tobacco
E. coli heat-labile toxin	Vaccine	Diarrhea	Transgenic maize Transgenic potato
Gastric lipase	Therapeutic enzyme pancreatitis	Cystic fibrosis,	Transgenic maize
Hepatitis B virus surface Antigen	Vaccine	Hepatitis B	Transgenic potato Transgenic lettuce

Source: ISAAA (2007) [43].

Table 2: Global Area of Biotech Crops in 2009 and 2010 by country (Million Hectares)

Country	2009	2010
USA*	64	66.8
Brazil*	21.4	25,4
Argentina*	21.3	22.9
India*	8.4	9.4
Canada*	8.2	8.8
China*	3.7	3.5
Paraguay*	2.2	2.6
Pakistan*	--	2.4
South Africa*	2.1	2.2
Uruguay*	0.8	1.1
Bolivia*	0.8	0.9
Australia*	0.2	0.7
Philippines*	0.5	0.5
Myanmer*	--	0.5
Burkina Faso*	0.1	0.3
Spain*	0.1	0.1
Mexico *	0.1	0.1
Colombia	<0.1	<0.1
Chile	<0.1	<0.1
Honduras	<0.1	<0.1
Portugal	<0.1	<0.1
Czech Republic	<0.1	<0.1
Poland	<0.1	<0.1
Egypt	<0.1	<0.1
Slovakia	<0.1	<0.1
Costa Rica	<0.1	<0.1
Romania	<0.1	<0.1
Sweden	--	<0.1
Germany	--	<0.1

*Biotech mega-countries which grew more than 50,000 hectares, or more of biotech crops in 2010.

Source: Clive James (2010) [44].

The use of plant-derived pharmaceuticals would undoubtedly assist vaccination programs in developing countries by reducing the costs of vaccine production, purification, storage and administration [40]. The International Service for the Acquisition of Agri-biotech Applications (ISAAA) estimated that by 2008, 13.3 million farmers were growing GM crops, including 12.3 million in developing counties. These comprised 7.1 million in China (*Bt* cotton), 5.0 million in India (*Bt* cotton) and 200,000 in the Philippines [41]. Several plant-derived pharmaceuticals are now in the pipeline for commercialization (Table 1). Substances produced in the plants must be guaranteed not to enter the regular food chain with a zero-tolerance threshold. Therefore, plants that are not used for food and feed purposes are better choices for product development, or approvals for third-generation GM crops which will be given for use under contained conditions only [42]. According to the ISAAA report on the global status of commercialized biotech/GM Crops in 2010, the area used for biotechnology crops was on the increase between 1996 to 2010 with only three African countries South Africa, Burkina Faso and Egypt growing biotech crops by small-scale farmers to meet the needs of citizenry. Of the 29 countries planting biotech crops in 2010, 17 countries planted 50,000 hectares or more by biotech crops (Table 2). Some countries in Africa have gradually accepted the benefits derived from biotechnology and are focusing on specific areas of research to improve the livelihood of the citizens [43]. A major concern for many developing countries is the lack of biosafety legislation for genetically modified plants and efficient education of farmers and small-scale holders of the benefits of biotechnology.

Criticisms Against GM Crops: There have been controversies and fears on the release of GM crops for commercial purpose. Some opponents of biotechnology are of the view that releasing such crops into the environment, may lead to an imbalance in the environment. Growing genetically modified plants in the field has raised concern for the potential transfer of genes from cultivated species to their wild relatives or non-target species. A controversy has arisen about whether certain genetically modified plants could harm not only insect pests but also other species such as the monarch butterfly which feeds on milkweed and the transfer of *Bt* toxin to crops. In the field, no significant adverse effects on non-target species have so far been reported. Nevertheless, there should be continuous monitoring for such effects. The broad consensus is that the environmental effects of genetically modified crops should be evaluated using science based assessment procedures, considering each crop individually in comparison to its conventional counterparts. Biosafety laws for regulation of this technology must be in place to ensure that the crops released for commercial purposes are eco-friendly and environmentally safe. Farmers need to be educated on the benefits of biotechnology in crop improvement and their confidence in the government would hasten acceptability. For food security to be sustained in Africa, utilization of agricultural biotechnology is of utmost importance.

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