ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 1
January 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2019; 19(1):13946-13958 DOI: 10.18697/ajfand.84.BLFB1029

Borlaug LEAP Paper

Potential Uses, Perceptions and Policy Issues of Genetically Modified Crops in Africa: A Case Study of Kenya

Kosgey Zennah[1,2]* and Kimani Cyrus[1,3]

Zennah Kosgey

*Lead author email: zennahk@gmail.com

[1]Kenya Agricultural and Livestock Research Organization, Food Crops Research Centre-Njoro, Kenya

[2]Department of Plant Pathology, University of Minnesota, St. Paul, MN, USA

[3]Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, MN, USA

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 1
January 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Abstract
Various genetic engineering techniques have been applied to develop genetically modified (GM) crops. These techniques have the greatest potential to address food insecurity and malnutrition problems in developing countries, for example, transgenic techniques have been successful in the development of bio-fortified cassava in Africa. Some techniques such as RNA interference (RNAi), virus induced gene silencing (VIGS) and CRISPR-Cas9 genome editing could also be of great use in developing disease and pest resistant or locally adapted cultivars. The GM crop adoption in Kenya has been hindered by lack of strong legislation structures, lack of knowledge about GM technology among the public and external influences. There is also lack of understanding about what GM crop development entails. There has been some progress in putting in place policies that build institutional capacity and regulate the use and handling of GM crops. These include the National Biotechnology Policy, the Biosafety Act of 2009, and the establishment of the National Biosafety Authority. Although Kenya has made some progress in putting in place legislations, the country is still far from incorporating the GM crops into the food system.

Key words: GM crops, Genetic engineering techniques, GM crop perceptions, Policy issues, Food security

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 19 No. 1 January 2019 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Introduction

Genetic engineering in crops is the manipulation of the deoxyribonucleic acid (DNA) to alter the crop's characteristic (phenotype) using modern biotechnology techniques such as genome editing, RNA interference (RNAi), virus induced gene silencing (VIGS) among others resulting to what is referred to as genetically modified (GM) crop. Gene manipulation can be done either through insertion or deletion of genes, change of gene structure or gene doubling (Karthikeyan *et al*., 2013; Vincelli, 2016). There are four categories of genetic engineering depending on the gene manipulation event or technique: (1) cisgenic-the inserted gene in a crop comes from a member of the same species, for example, a gene of wheat origin inserted into a wheat variety, (2) intragenic-the inserted gene comes from a member of a different but close species, for instance, from barley to wheat, (3) transgenic-the inserted gene is from a different species, for example, the inserted gene in *Bt* (*Bacillus thuringiensis*) maize came from the *Bacillus thuringiensis* bacterium, (4) subgenic-the crop's gene is manipulated in vitro without inserting any new gene for example, gene deletion using genome editing techniques (Sticklen, 2015). Most of the gene insertion events are done using bacterial sequences which can deliver genes into the plant genome (Ramadevi *et al*., 2014). Genome editing is currently not considered transgenic because it does not leave any foreign DNA sequences in the crop, making the crop improvement process more efficient either by complementing or substituting the conventional breeding methods (Sharma *et al*., 2002).

Can GM crops curb food insecurity and malnutrition problems?

The genetic engineering techniques such as RNAi, VIGS and genome editing are efficient and have the potential to address current challenges in developing countries such as malnutrition (through biofortification), pests and diseases, abiotic stresses and shelf life on staple food crops such as cassava (*Manihot esculenta*), sweet potatoes (*Ipomoea batatas*), maize (*Zea mays*), rice (*Oryza sativa*) and wheat (*Triticum aestivum)* (Sharma *et al*., 2002). The debate on whether agricultural biotechnology techniques especially genetic modification can enhance food security, reduce poverty and improve human development is still contributing to delays in most African countries to embrace the new technologies (Singh *et al*., 2006).

Some studies have demonstrated the potential of genetic engineering techniques in eliminating or minimizing malnutrition problems as well as biotic and abiotic threats on cassava, sweet potatoes, maize, rice and wheat (Collinge *et al.,* 2008; Duan *et al*., 2012; Wang *et al*., 2014; Wang *et al*., 2016; Shi *et al*., 2017). Cassava and sweet potatoes are traditional crops which are often termed as 'orphan crops' because for many years, not much attention has been paid to them although currently, there is more research on these crops (Anderson, 2018). These crops which are highly consumed in Africa lack essential nutrients leaving most consumers malnourished (Muthoni and Nyamongo, 2010). However, these 'orphan crops' have better tolerance to abiotic stresses such as drought and are therefore cost effective to produce. The main threats to these crops are viral diseases, whose current effective control measure is the complete elimination of infected plants, posing a food security threat to most resource poor farmers who depend on these crops as their daily meal and their main source of income (Mukhopadhyay *et al*., 2011; Gibson *et al*., 2014; Adikini *et al*., 2016). Genetic engineering techniques such as RNAi and genome editing are among the most promising approaches in eliminating or minimizing the threats by viral diseases as well as improving the nutritional quality of these crops (Tepfer, 1993, Bart and Taylor, 2017).

Some of the drawbacks in cassava as a crop are being addressed by the Bio Cassava plus (BC+) program. This program was established as one of the GC-9 projects under the Grand Challenges in Global Health (GCGH) program funded by Bill and Melinda Gates Foundation and its main objective was to address malnutrition problems in Sub-Saharan Africa by developing staple food crops that are more nutritious. The program also focuses on developing cassava crops with reduced cyanogen, increased shelf life and resistance to viral diseases using modern biotechnology techniques (Takeshima, 2010; Sayre *et al*., 2011). The use of these techniques on the 'traditional' cassava crop led to an improved 'biofortified' cassava which was rich in nutrients such as iron, protein, vitamin A and zinc, resistant to viral diseases and with a longer shelf life compared to the traditional unimproved varieties (Sayre *et al*., 2011).

Sweet potato has also been improved using genetic engineering techniques like gene silencing (Kreuze *et al*., 2008). Currently, there are two varieties of sweet potatoes; white-fleshed and orange-fleshed. The former is vitamin A deficient while the latter (biofortified) has beta-carotene which is used by the body in producing vitamin A (Muthoni and Nyamongo, 2010). Despite the importance of the crop especially to small scale farmers, its production is mainly threatened by viral diseases such as Sweet potato feathery mottle virus (SPFMV), Sweet potato mild mottle virus (SPMMV), Sweet potato virus G (SPVG), Sweet potato chlorotic stunt virus (SPCSV), Sweet potato latent virus (SPLV), Sweet potato caulimo-like virus (SPCV), Sweet potato ring spot virus (SPRSV) and Cucumber mosaic virus (CMV). Some of these diseases can cause up to 98% yield loss, either individually or in combination posing a threat to food security (Karyeija *et al*., 1998; Ngailo *et al*., 2013; Gibson *et al*., 2014; Adikini *et al*., 2016). These diseases are difficult to control using biological or chemical measures, therefore planting resistant cultivars remains the most effective control measure. A transgenic sweet potato cultivar '*Blesbok'* developed in South Africa using the gene silencing technique to target the coat protein genes of the SPFMV, SPCSV, SPVG and SPMMV was found to have some level of resistance to these viral diseases compared to the conventional cultivars (Sivparsad and Gubba, 2014). This study is a good example of how genetic engineering could solve the complex disease menace in one of Africa's food security crops.

Maize, another staple food crop, is currently threatened mainly by pests and disease such as stem borers, fall armyworm and maize lethal necrosis (MLN) (De Groote, 2002; Mahuku *et al*., 2015; KALRO, 2018). The problem caused by stem bores on maize led to the development of *Bt* maize that produces insecticidal proteins providing resistance to African stem borer (*Busseola fusca*) and the Chilo borer (*Chilo partellus*) (Fischer *et al*., 2015). Currently in Kenya, fall armyworm is a big threat to maize production and *Bt* maize has the potential of reducing the losses due to the pest damage. However, in Africa it is only South Africa that has commercialized *Bt* maize production, mainly due to biosafety regulations and public perception issues in other countries. Despite its commercialization in South Africa, *Bt* maize production by smallholder farmers has been reported to be faced by a couple of challenges. First, the resource poor smallholder farmers cannot afford to maintain the recommended conditions for *Bt* maize production such as using the recommended fertilizer rates and providing good storage conditions. Secondly, rainfall fluctuations have led to higher yields from the locally adapted non-GM maize hybrids and the open pollinated varieties (OPVs) compared to the *Bt* maize, due to their local adaptation. Thirdly, the regulations that accompany planting of *Bt* crop such as complying with the biosafety management practices and the need of buying *Bt* maize seeds every season discouraged most smallholder farmers, who opted for the non-GM hybrids and OPVs (Fischer *et al*., 2015).

Genetically modified crops also have the potential to address some major health issues through disease prevention, a few examples being *Bt* maize and transgenic rice (rice-based oral antibody). *Bt* maize has the potential to reduce risks of fumonisin, a carcinogenic toxin produced by the *Fusarium* fungi ending up in the food chain (Clements *et al*., 2003; Hammond *et al*., 2004; IFRI, 2013). One of the predisposing factors to *Fusarium* infection is the damage created on maize kernels by stalk borers. Fumonisin is known to cause esophageal cancer and it was found in high concentration in non-*Bt* maize, whereas the *Bt*-maize had significantly lower levels (IFRI, 2013). In Kenya, rotavirus infections have been reported to account for high mortality rate in children below 5 years (Tate *et al*., 2009). A rice-based oral antibody produced through genetic engineering was found to provide immunity against rotavirus infection (Tokuhara *et al*., 2013). This rice-based antibody could be useful in reducing the rotavirus health burden, hence saving lives, money and time spent on hospital visitations.

These important and insightful studies underscore the importance of GM crops adoption in Africa. However, this cannot happen given the prevailing negative public perceptions surrounding the GM crops coupled with lack of suitable policies regarding adoption of such crops.

Table1: Examples of GM crops and their potential benefits

GM Crop	Potentials benefits
Bt cotton	Reduced crop losses hence increased economic gains
Bt maize	Reduced mycotoxin contamination in food
Rotavirus vaccine complemented rice	Reduced child mortality due to reduced rotavirus infections
Golden rice	Increased nutritional value, specifically vitamin A
Virus resistant sweet potato	Reduced crop losses and increased tuber marketability
Bio-fortified cassava	Increased nutritional value e.g. iron, protein, vitamin A and zinc

Public perceptions and factors hindering adoption of GM crops

Genetically modified crops have generated considerable debate and controversy which has led to most African countries banning their use and importation (Nang'ayo, 2012).

GM crops can be judged using two principles; (i) principle of substantial equivalence, and (ii) precautionary principle (Myhr and Traavik, 2012). The principle of substantial equivalence uses scientific evidence to ascertain the safety of GM crops, while the latter is based solely on a pessimistic bias towards such crops. Adoption of GM crops by most African countries has been hindered by several factors, miscommunication being the biggest. Most people do not have scientific knowledge about GM crops and therefore have a wrong perception about them (Ezezika *et al*., 2012). This is further compounded by the fact that most scientists do not engage the public on issues concerning GM crops, therefore leading to non-scientific public debates hence the misconception about these crops. The situation is worsened often by leaders and policy makers who without clear information about GM crops pass on the wrong perception to the public. This has been observed often whenever there is a public debate over GM crops with such debates being skewed towards the precautionary principle and totally ignoring the principle of substantial equivalence. In addition, due to shortage of extension officers who can easily reach many farmers in the villages, farmers cannot access detailed/clear information about GM crops (Ezezika *et al*., 2012). The negative campaign by some non-governmental organizations and anti-GM groups have also contributed to the increased negative perception about GM crops by the public. However, the delays in development and implementation of biosafety regulations supposed to govern GM crops in most African countries could be hindering the acceptance and commercialization of the crops.

It is also thought that the development of GM crops in developed countries could be contributing to their slow adoption by African communities. This is because some people think that the developed countries take advantage of African countries through their innovations, and that the adoption could be faster if the GM crops were locally developed (Ezezika *et al*., 2012). Some government research institutions, non-governmental organizations (NGOs) and seed companies are against research done by some private companies especially concerning the GM crops and this to an extent, increases the public's negative perception about the crops. Another barrier to the adoption of GM crops is culture, for example, women in most African communities are farmers, whereas men take up other careers and are mainly the decision makers in their families. Even though women could be willing to fully adopt GM crops, their men could be the barriers due to the misconceptions about the crops.

Government policies

Kenya has made some progress in putting in place policies and institutional capacity to regulate the use and handling of GM crops. This is through passing some legislations like the National Biotechnology Policy and the Biosafety Act of 2009, the latter laying the foundation for the establishment of the National Biosafety Authority. Although some progress has been made, the country is still far from allowing the incorporation of GM crops into the food system. This is evident by the fact that only a few confined field trials of GM crops such as *Bt* maize and *Bt* cotton have been approved.

External influence has had an impact on government policies. For example, allowing some of the confined field trials to be carried out was apparently due to pressure from some funding agencies and biotechnology companies (Ecowatch, 2016). Another

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 1
January 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

external influence is mainly due to the negative policies of the European Union (EU) towards GM crops. The EU is one of the biggest markets for Kenyan horticultural produce and therefore any policies or attitudes on the part of the EU has a direct impact on Kenyan policies concerning GM crops (Ecowatch, 2015; Daily Nation, 2015).

Concerns about GM crops

Despite the proposed paradigm shift from the non-GM to GM crops, there are several concerns about these crops. Some GM crops have been developed to have a broad-spectrum resistance to herbicides (Duke, 1998). The first herbicide resistant GM crops were bromoxynil-resistant cotton and glufosinate-resistant canola introduced in 1995 (Duke, 2014). These crops can withstand heavy use of herbicides as a way of protecting them from herbicides used to control weeds. This, however encourages excessive use of herbicides which might have unintended harmful effects on other plants and organisms in the ecosystem (Van Bruggen *et al*., 2018). Moreover, some weeds have developed herbicide resistance probably due to the heavy usage of herbicides. There are also concerns about transfer of herbicide resistance genes among or within species and this has been demonstrated in canola fields (Rieger *et al*., 2002). However, herbicide resistance in weeds is not attributable only to GM crops as it had been documented even before the introduction of herbicide resistant GM crops (Holt and Lebaron, 1990).

The potentially adverse effects of *Bt* crops on non-target organisms is another issue of concern (Robinson, 1996; O'Callaghan *et al*., 2005). Some studies have documented adverse effects on non-target organisms especially *Lepidopteran* species like monarch butterfly larvae (Losey *et al*., 1999; Hansen and Obrycki, 2000). However, a study by Saxena and Stotzky (2001) showed that a toxin released from root exudates and biomass of *Bt* corn had no effect on bacteria, fungi, protozoa, nematodes and earthworms. Another concern is the evolution of super resistant pests that can overcome the resistance in the transgenic plants (Peferoen, 1997). Some studies have conducted laboratory induced resistance to *Bt* crops though there is evidence of field-evolved resistance in the pink bollworm, which mainly attacks cotton (Dhurua and Gujar, 2011).

The allergenicity of GM products is another concern raised since some gene modifications result into the production of new proteins in the crop. There is a documented study on patients having allergic reaction to a protein transferred from brazil-nut to soybean (Nordlee *et al*., 1996; Bansal *et al*., 2007). Allergenicity tests should be done on the introduced proteins just to make sure that there are no adverse effects on the human body (Taylor and Hefle, 2001).

In addition, there are concerns that the GM crops are likely to contaminate the non-GM crops (for those not willing to plant GM crops), through cross-pollination, and this could even lead to restriction of exports of the produce. There is also a concern about high probabilities of gene flow from GM crops to other non-GM plants leading to genetic contamination.

DOI: 10.18697/ajfand.84.BLFB1029

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 1
January 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

There are many pertinent questions to consider as many African countries are under pressure to adopt the GM crops; are the governments, potential crop producers, food industries, and testing laboratories ready to accurately test GM crops, foods and food ingredients to comply with biosafety regulations? Can they afford the appropriate facilities and equipment to carry out tests or analysis? Do they have the expertise? Despite the pressure for developing countries to adopt GM crops, care must be taken to maintain safety for human health and the environment.

In conclusion, as the push for GM crops adoption continues, we must maintain a sober debate based on the principle of substantial equivalence. Regulatory measures should be heightened to ensure complete safety assessment of the GM crops before their commercialization.

DOI: 10.18697/ajfand.84.BLFB1029

References

Adikini S., Mukasa S.B., Mwanga R.O.M. and Gibson R.W. (2016). Effects of Sweet Potato Feathery Mottle Virus and Sweet Potato Chlorotic Stunt Virus on the Yield of Sweet Potato in Uganda. *Journal of Phytopathology*. 164: 242-254.

Anderson A. (2018). https://www.genomeweb.com/genetic-research/african-orphan-crops-consortium-tackles-101-crop-genomes-training-africa. Accessed January 30, 2019.

Bansal A.S., Chee R., Nagendran V., Warner A. and Hayman G. (2007). Dangerous Liaison: Sexually Transmitted Allergic Reaction to Brazil Nuts. *Journal of Investigational Allergology and Clinical Immunology*. 17: 189-191.

Bart R.S., Taylor N.J. (2017). New opportunities and challenges to engineer disease resistance in cassava, a staple food of African small-holder farmers. *PLoS Pathogens* 13(5).

Clements M.J., Campbell K.W., Maragos C.M., Pilcher C., Headrick J.M., Pataky J.K. and White D.G. (2003). Influence of Cry1Ab protein and hybrid genotype on Fumonisin contamination and fusarium ear rot of corn. *Crop Science*. 43: 1283-1293.

Collinge D.B., Lund O.S. and Thordal-Christensen H. (2008). What are the prospects for genetically engineered, disease resistant plants? *European Journal of Plant Pathology*. 121: 217-231.

Daily Nation (2015). Kenya's global market share of horticulture on the decline. http://www.nation.co.ke/lifestyle/smartcompany/Kenyas-global-market-share-of-horticulture-on-the-decline/-/1226/2602694/-/hmnbr/-/index.html. Accessed on May 20, 2017.

De Groote H. (2002). Maize yield losses from stemborers in Kenya. *Insect Science Application*. 22 (2): 89-96.

Dhurua S. and Gujar T.G. (2011). Field-evolved resistance to *Bt* toxin Cry1Ac in the pink bollworm, Pectinophoragossypiella (Saunders) (Lepidoptera: Gelechiidae), from India, *Pest Management Science*. 67: 898-903.

Duan C.G., Wang C.H. and Guo H.S. (2012). Application of RNA silencing to plant disease Resistance. *Silence. 3:5*

Duke S.O. (1998). Herbicide resistant crops-their impact on weed science. *Journal of Weed Science and Technology*. 43:94-100.

Duke S.O. (2014). Perspectives on transgenic, herbicide-resistant crops in the United States almost 20 years after introduction. *Pest Management Science*.71: 652-657.

Ecowatch (2016). Monsanto and Gates Foundation Pressure Kenya to Lift Ban on GMOs http://ecowatch.com/2016/01/07/kenya-gmo-ban/. Accessed on May 27, 2017.

Ecowatch (2015). It's Official: 19 European Countries Say 'No' to GMOs, http://ecowatch.com/2015/10/05/european-union-ban-gmos/. Accessed on May 20, 2017.

Ezezika O.C., Daar A.S., Barber K., Mabeya J., Thomas F., Deadman J., Wang D. and Singer P.A. (2012). Factors influencing agbiotech adoption and development in Sub-Saharan Africa. *Nature Biotechnology*. 30: 38-40.

Fischer K., Van den Berg J. and Mutengwa C. (2015). Is *Bt* maize effective in improving South African smallholder agriculture? *South African Journal of Science*. 111(1/2).

Gibson W.R., Waswa P. and Tufan H.A. (2014). The ability of cultivars of sweet potato in East Africa to 'revert' from Sweet potato feathery mottle virus infection. *Virus Research*. 186: 130-134.

Hammond B.G., Campbell K.W., Pilcher C.D., Degooyer T.A., Robinson A.E., McMillen B.L., Spangler S.M., Riordan S.G., Rice L.G. and Richard J.L. (2004). Lower fumonisin mycotoxin levels in the grain of Bt corn grown in the United States in 2000-2002. *Journal of Agricultural and Food Chemistry*, 52: 1390-1397.

Hansen J.L. and Obrycki J.O. (2000). Field deposition of *Bt* transgenic corn pollen: lethal effects on the monarch butterfly, *Oecologia*. 125: 241-248.

Holt J.S. and Lebaron H.M. (1990). Significance and Distribution of Herbicide Resistance, *Weed Technology*. 4:141-149.

International Food Policy Research Institute (IFPRI). (2013). Genetically modified crops in Africa: economic and policy lessons from countries south of the Sahara. Edited by José Falck-Zepeda, Guillaume Gruère, and IdahSithole-Niang, pp 43-59.

KALRO (2018). Identification and Management of Fall Armyworm in Kenya http://www.kalro.org/sites/default/files/KALRO-FAW-A5brochure11April2018.pdf. Accessed January 30, 2019.

Karyeija R.F., Gibson R.W. and Valkonen J.P.T. (1998). The significance of sweet potato feathery mottle virus in subsistence sweet potato production in Africa. *Plant Disease*. 82(1).

Karthikeyan A., Deivamani M., Shobhana V.G., Sudha M. and Anandhan A. (2013). RNA interference: evolutions and applications in plant disease management. *Archives of Phytopathology and Plant Protection*, 46 (12): 1430-1441.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 19 No. 1 January 2019 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Kreuze F.J., Klein S.I., Lazaro U.M., Chuquiyuri W.J., Morgan G.L., Mejia P.G., Ghislain M. and Valkonen J.P. (2008). RNA silencing-mediated resistance to a crinivirus (closteroviridae) in cultivated sweetpotato (*ipomoea batatas* l.) and development of sweetpotato virus disease following co-infection with a potyvirus. *Molecular Plant Pathology.* 9(5): 589-598.

Losey J.E., Rayor L.S. and Carter M.E. (1999). Transgenic pollen harms monarch larvae. *Nature*. 399:214.

Mahuku G., Lockhart B.E., Wanjala B., Jones M.W., Kimunye J.N., Stewart L.R., Cassone B.J., Sevgan S., Nyasani J.O., Kusia E., Kumar P.L., Niblett C.L., Kiggundu A., Asea G., Pappu H.R., Wangai A., Prasanna B.M. and Redinbaugh M.G. (2015). Maize Lethal Necrosis (MLN), an Emerging Threat to Maize-Based Food Security in sub-Saharan Africa. *Phytopathology.* 105(7):956-65.

Muthoni J. and Nyamongo D.O. (2010). Traditional food crops and their role in food and nutritional security in Kenya. *Journal of Agricultural and Food Information.* 11:36-50.

Mukhopadhyay S.K., Chattopadhyay A., Chakraborty I., Bhattacharya I. (2011). Crops that feed the world, Sweet potatoes for income and food security. *Food Security*. 3:283-305.

Myhr A.I. and Traavik T. (2012). Genetically Modified (GM) Crops: Precautionary Science and Conflicts of Interest. *Journal of Agricultural and Environmental Ethics*. 16: 227-247.

Nang'ayo F. (2012) OPINION - Kenya's ban on imports GM crops, http://aatf-africa.org/opion-kenya-ban-on-gm. Accessed May 27, 2017.

Ngailo S., Shimelis H., Sibiya J. and Mtunda K. (2013). Sweet potato breeding for resistance to sweet potato virus disease and improved yield: Progress and challenges: *African Journal of Agricultural Research*. 8: 3202-321.

Nordlee J.A., Taylor S.L., Townsend J.A., Thomas L.A. and Bush R.K. (1996). Identification of a Brazil-nut allergen in transgenic soybeans. *New England Journal of Medicine.* 334(11):688-92.

O'Callaghan M., Glare T.R., Burgess E.P.J. and Malon L.A. (2005). Effects of plants genetically modified for insect resistance on nontarget organisms. *Annual Review of Entomology*. 50:271-292.

Peferoen M. (1997). Progress and prospects for field use of *Bt* genes in crops. *Trends in Biotechnology*. 15:173-177.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 1
January 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Ramadevi A., Rao K.V. and Reddy V.D. (2014). Agrobacterium tumefaciens-mediated genetic transformation and production of stable transgenic pearl millet (Pennisetum glaucum [L.] R. Br.). *In Vitro Cellular and Developmental Biology*. 50:392-400.

Rieger M.A., Lamond M., Preston C., Powles S.B. and Roush R.T. (2002). Pollen-Mediated Movement of Herbicide Resistance between Commercial Canola Fields. *Science*. 96:2386-2388.

Robinson D.J. (1996). Environmental risk assessment of releases of transgenic plants containing virus-derived inserts. *Transgenic Research*. 5:359-362**.**

Sayre R., Beeching J.R., Cahoon E.B., Egesi C., Fauquet C., Fellman J., Fregene M., Gruissem W., Mallowa S., Manary M., Maziya-Dixon B., Mbanaso A., Schachtman D.P., Siritunga D., Taylor N., Vanderschuren H. and Zhang P. (2011). The Bio-Cassava plus program: Biofortification of cassava for Sub-Saharan Africa. *Annual Review of Plant Biology*. 62:251-272.

Saxena D. and Stotzky G. (2001). Bacillus thuringiensis (*Bt*) toxin released from root exudates and biomass of *Bt* corn has no apparent effect on earthworms, nematodes, protozoa, bacteria, and fungi in soil. *Soil Biology and Biochemistry*. 33: 1225-1230.

Sharma H.C., Crouch J.H., Sharma K.K., Seetharama N. and Hash C.T. (2002). Applications of biotechnology for crop improvement: prospects and constraints. *Plant Science*. 163: 381-395.

Shi J., Gao H., Wang H., Lafitte H.R., Archibald R.L., Yang M., Hakimi S.M., Mo H, Habben J.E. (2017). ARGOS8 variants generated by CRISPR-Cas9 improve maize grain yield under field drought stress conditions. *Journal of Plant Biotechnology.*15: 207-216.

Sivparsad B.J. and Gubba A. (2014). Development of transgenic sweet potato with multiple virus resistance in South Africa (SA). *Transgenic resistance*. 23: 377-388.

Singh O.V., Ghai S., Paul D. and Jain R.K. (2006). Genetically modified crops: success, safety assessment and public concern. *Applied Microbiology and Biotechnology*. 71: 598-607.

Sticklen M. (2015). Transgenic, Cisgenic, Intragenic and Subgenic crops. *Advances in Crop Science and Technology*. Vol 3 (2).

Taylor S.L. and Hefle S.L. (2001). Will genetically modified foods be allergenic? *Journal of Allergy and Clinical Immunology*. 107:765-71.

Tate J.E., Rheingans R.D., O'Reilly C.E., Obonyo B., Burton D.C., Tornheim J.A., Adazu K., Jaron P., Ochieng B., Kerin T.K., Calhoun L.M., Hamel M.J., Laserson K.F., Breiman R.F., Feikin D.R., Mintz E.D. and Widdowson M. (2009). Rotavirus

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 19 No. 1 January 2019 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

disease burden and impact and cost-effectiveness of a rotavirus vaccination program in Kenya. *The Journal of infectious diseases*. 200 Suppl 1, S76-84.

Takeshima H. (2010). Prospects for Development of Genetically Modified Cassava in Sub- Saharan Africa. *Agricultural Biotechnology Forum*. 13: 63-75.

Tepfer M. (1993). Viral genes and transgenic plants. *Biotechnology*. 11:1125-1132.

Tokuhara D., Álvarez B., Mejima M., Hiroiwa T., Takahashi Y., Kurokawa S., Kuroda M., Oyama M., Kozuka-Hata H., Nochi T., Sagara H., Aladin F., Marcotte H., Frenken L.G.J., Iturriza-Gómara M., Kiyono H., Hammarström L. and Yuki Y. (2013). Rice-based oral antibody fragment prophylaxis and therapy against rotavirus infection. *Journal of Clinical Investigation*. 123: 3829-3838.

Van Bruggen A.H.C., He M.M., Shin K., Mai V., Jeong K.C., Finckh M.R, Morris J. G. Jr. (2018). Environmental and health effects of the herbicide glyphosate. *Science of the Total Environment*:255-268.

Vincelli P. (2016). Genetic Engineering and Sustainable Crop Disease Management: Opportunities for Case-by-Case Decision-Making. *Sustainability*, 8, 495.

Wang Y., Cheng X., Shan Q., Zhang Y., Liu J., Gao C., Qui J.L. (2014). Simultaneous editing of three homoeoalleles in hexaploid bread wheat confers heritable resistance to powdery mildew, *Nature Biotechnology.* 32: 947-951.

Wang F., Wang C., Liu P., Lei C., Hao W., Gao Y., Liu Y, Zhao K. (2016) Enhanced Rice Blast Resistance by CRISPR/Cas9-Targeted Mutagenesis of the ERFTranscription Factor Gene OsERF922. *PLoS ONE.* 11(4).