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Review

Prospects of genetic modified maize crop in Africa

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Genetic modified maize crop increases annually as a result of food insecurity and limited land caused by rapid population increase of over seven billion in the world. Scientists have been playing their role to address this food insecurity problem. The use of genetically modified (GM) maize crop to feed people is one of the proposed ways, because it yields more compared to the conventional varieties. However, there are several contradictions which hinder the adoption of this new technology. Some studies have shown that GM maize is risky to human health, animals and not friendly to environmental conservation, which may lead to the death of other bio-diversities. Generally, other studies have supported the consumption of GM maize. However, after being approved by the scientist in the countries concerned, the GM maize varieties which seem to be hazardous to human health must be prohibited in research centres so as to avoid transportation to other countries. Regarding the new technology of GM maize, the conventional method of breeding is still important to keep maize seeds available in the gene bank. Therefore, researchers should consider this for further research issues on maize improvement.

Key words: *Bacillus thuringensis*-maize, *Bacillus thuringensis* protein, conventional breeding, environment, food crisis, genetic modified maize, genetic modified organism, health risk, landraces.

INTRODUCTION

Genetically modified (GM) maize ranked the second most important transgenic crop globally. It is planted in an area that accounts for 24% of global biotech crop area and about 14% of total maize grown globally (James, 2005). Farmers have rapidly adopted genetically modified organism (GMO) technology including GM maize crops (Lawson et al., 2009). GMO technology involves the incorporation of genetic engineering to improve crop productivity since over one billion people in the world face starvation and two billion people suffer from one or more micronutrient deficiencies, especially vitamin A, iodine and iron, often lumped as hidden hunger (Alnwick, 1996). The technology has been adopted by most of the developed countries which previously were not aware of it. GM crops are also used for food security purpose (Chondie and Kebede, 2015). GM crops were first grown commercially worldwide in 1996 (James, 2007). Due to the advancement of biotechnology, a number of GM or transgenic crops carrying novel traits have been developed and released for commercial purpose (Arthur, 2011). In GM maize crops technology, the desired traits are inserted into plant, unlike the conventional breeding methods, where traits from two crops are combined; for instance, maize crops (James, 2013; Chondie and

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Table 1. Genetically modified maize crop development in sub-Saharan Africa (Namuddu and Grumet, 2013).

Country	Crop/Trait	Status
Kenya	Maize/Stem borer resistance	Confined field trials
	Maize drought tolerance	Confined field trials
Mozambique	Maize/Drought tolerance	Stalled: awaiting regulatory framework
South Africa	Maize streak virus resistance	Greenhouse containment
	Maize/Drought tolerance	Greenhouse containment
Tanzania	Maize/Drought tolerance	Stalled: awaiting regulatory framework
Uganda	Maize/Drought tolerance	Confined field trials

Kebede, 2015). GM maize is useful for livestock and human consumption (Clive, 2008).

Resistance to herbicide as well as insect is the most common trait that has been incorporated into GM maize. GM crops contain proteins that make them herbicide tolerant (Ht) and insect resistant (USDA, 2011). Herbicide tolerant crops are engineered to produce one or more proteins which allow them to survive even if sprayed with herbicides (Carman et al., 2013). A number of studies conducted have shown a significant number of GM crops which are approved for human and animal use. Crops containing several GM genes 'stacked' into one plant are among the recommended for consumption (Carman et al., 2013). GM maize varieties are common in some countries like United States of America (USA) (USDA, 2011). The GM maize from USA contains Ht or *Bacillus thuringiensis* traits, or a 'stacked' combination of them (Pioneer Hi-Bred, 2012). Of this, 2004 GMO technology accounted for 23% of all GM crops produced (James, 2004). It has been projected that in the coming decades, human population will reach over nine billion (Pinstrup-Andersen, 2010a, b). Therefore, the production of GM maize should not be stopped so as to make the new approved beneficial traits available to people (James, 2007). The common producers of GM maize globally are dominated by USA having 59% of land for production, followed by Argentina with 20%, Canada and Brazil with 6% each, and China with 5% of land. GM maize is in the initial stage in Africa (Moola and Munnik, 2007). Of all countries in African, only South Africa and Egypt have introduced new commercialized GM maize. However, Zimbabwe, Kenya, Nigeria, Mali, Egypt, and Uganda have also adopted GM maize in Africa. Other countries are still engaging in GM research, whereas others are in trials including Benin, Burkina Faso, Cameroon, Ghana, Malawi, Mauritius, Morocco, Namibia, Niger, Senegal, Tanzania, Tunisia, and Zambia (Moola and Munnik, 2007). Table 1 shows some of the GM crops under research in sub Saharan Africa.

Several studies on GM maize have been done to either introduce herbicide-tolerance (for instance Roundup (R)) or to produce a modified *B. thuringiensis* toxin insecticide or both (Seralini et al., 2014). Results have shown that these GM crops contain new pesticide residues for which new maximum residue levels (MRL) have been established in some countries. However, herbicide (glyphosate) tolerance and *B. thuringiensis* toxins make crop plants inedible to some insects (GineBordonaba, 2011; Hammond et al., 2006). It has been reported that no major physiological changes are attributable to the consumption of GM maize in sub-chronic toxicity studies (GineBordonaba, 2011; Hammond et al., 2006). GM maize crop has offered some solutions to future food production. According to Tirado and Johnston (2010), although solutions to food have been provided by GM maize, there has been increase in farmers' dependence on agro-industries compared to non-GM maize seed which farmers believe to be safe with less cost. An example of GM maize crop which has been approved for cultivation in Europe is MON 810 maize (Monsanto). It contains a Cry gene from the bacterium *B. thuringiensis*, which expresses *B. thuringiensis* protein, a toxin of insecticidal properties (Tirado and Johnston, 2010). Most European countries have banned the cultivation of GM maize, because biotechnological industries are not interested in introducing GM varieties resistant to drought, soil salinity, and cold due to their low marketing potential (Lisowska, 2011). Therefore, this review paper aims to explore the constraints, benefits, risk to human and animals' health and environment as well as the controversy of GM maize.

CONSTRAINTS OF GM MAIZE CROP

Studies about GM maize were reported for the first time in Africa through food aid shipments which were given in Southern Africa during the food crisis that occurred in 2002 (Zerbe, 2004). New GM technology is introduced due to critical food shortages caused by a number of factors including climate change, limited arable land, water shortage, pests and diseases, debt, collapsing public services, and poor governance (ISF, 2011). However, Africans were not happy with GM maize. They debated against agricultural biotechnology, refusing to use GM products (Zerbe, 2004). Although GM maize prevents hunger, its safety has not been proved in any documents. Therefore, the countries which oppose GM maize could be correct to maintain health status (Konig et al., 2004; Seralini et al., 2009). Rats fed with the genetic modified maize (NK 603, MON 810, and MON 863), revealed 3 new GMOs side effects, which were sex and often dose-dependent (Spiroux de Vendômois et al., 2009). More side effects were observed in kidney and liver, the dietary detoxifying organs (Spiroux de Vendomois et al., 2009). It has been estimated that GM maize crop is taken up quickly than any other agricultural technology which is currently used by 16 million farmers (James, 2007). Maize imports from United States and Mexico seem to be worse in terms of subsistence farmers' trade. Hence, the production has been reported to decrease due to the loss of local varieties of maize and this would lose their resilience to environmental stress through contamination with genetically modified maize (Zietz and Seals, 2006).

European Corn Borer (ECB) is one of the major pests that have been affecting maize (corn) crops in North America for over 60 years (Park et al., 2011). The pest was controlled by dichlorodiphenyltrichloroethane (DDT) which later had negative effects; therefore, it was rejected. Organophosphate and pyrethroids were subsequently used (Park et al., 2011). The strains with high resistance to European corn borer were developed by plant breeders. The mixture showed success with transgenic maize expressing insecticidal protein derived from *B. thuringiensis* (Kaster and Gray, 2005). Avidin, produced commercially in GM maize for use in research and diagnostics, is toxic to certain insects (Park et al., 2011). There are also environmental issues relating to gene flow from GM crops to non-GM crops which may disturb genotypes and lower production. Further studies are needed to confirm the usefulness of GM maize to avoid risk to human and animals (Park et al., 2011). Left-over grains from GM maize modified to express biopharmaceutical compounds have been reported to germinate with soybeans grown on the same field in the season following the trial. This may cause contamination. GM maize technology has affected seed markets. An agrochemical company, Monsanto which has not been registered as traditional breeder, took advantage of seed production during the establishment of genetic engineering. The company made patents and use an opportunity to access the market and implement new strategies to obtain maximum profit (Vandana et al., 2011). Prices for seeds are increasing and the number of farmers using seeds from their own harvest is being endangered steeply and may likely disappear completely (Jacobsen et al., 2013).

BENEFITS OF GM MAIZE CROP

Genetic modified crops may provide better quality food, higher nutritional yields, inexpensive and nutritious food, crops and produce that require less chemical application, such as herbicide resistant maize. Previously, GM maize was grown for commercial purpose in 11 countries, including United States, Brazil, Argentina, South Africa, Canada, Philippines, and Spain (Singh et al., 2014). From the African perspective, GM technology so far has been deployed only in South Africa, Zimbabwe, Egypt, Kenya, Burkina Faso, Uganda, Malawi, and Mauritius. Of these, few countries, South Africa, Egypt, and Burkina Faso have commercialized their crops (Arthur, 2011; ASSAF, 2010). Since its introduction, GM technology has been found to reduce losses of maize incurred through damage by stem borers (Wanyama et al., 2004) and reduce herbicides application by introducing *B. thuringiensis* maize through transgenesis. *B. thuringiensis* maize used is of a better grain quality, and increases farmers' competitiveness; a healthier product, like mycotoxin is consistently well below mandatory regulations (Barros et al., 2009). Enrichment of transgenic maize in specific alimentary products makes such maize foods to frequently have higher utility value than traditional food products. The group of nutraceutics contains, first of all, vitamins A, C, E, plant pigments, alimentary cellulose, and pre- and probiotics (Kosicka-Gębska et al., 2009). The leading examples of cultivable edible vaccines are exemplified by varieties of rice, maize, soybean or potato, capable of producing antigens against various infections, including the effects of *Escherichia coli* toxins, rabies, infections of *Helicobacter pyloribacteria*, and viral type B hepatitis (Kramkowska et al., 2013). Several studies have reported that the reduction of pest damage after the introduction of *B. thuringienssis* maize instead of conventional maize results in enhanced yield (Huesing and English, 2004). At commercial level, after the approval of the glyphosate-tolerant soybeans, other twenty events have been approved for planting, food and feed consumption and commercialization, including 15 maize varieties. Gouse et al. (2005) found that large-scale commercial maize farmers benefit economically from the use of insect resistant yellow maize. Despite paying more for seeds, farmers who adopted *B. thuringiensis* yellow maize unlike conventional maize had increased income through savings from pesticides and increased yield due to better pest control (Huesing and English, 2004). Corn has been deliberately genetically modified to establish agronomically desirable traits. Traits that have been engineered into corn include resistance to herbicides and resistance to insect pests, the latter being achieved by incorporation of a gene that codes for the *B. thuringiensis* toxin (Singh et al., 2014). GM maize varieties with high resistance to glyphosate herbicides have been produced. Pioneer Hi-Bred marketed corn hybrids with tolerance to imidazoline herbicides under the trademark "Clearfield" beng in Canada markets. Though in these hybrids, the herbicide-tolerance trait was bred without the use of genetic engineering. Therefore, these corn hybrids do not apply imidazoline-tolerant corn (Singh et al., 2014). The utilization of pesticides and herbicides globally has decreased. The decrease is due to the emergence of GM maize technology. However, there may be some variations of response from one variety to another (Benbrook, 2012). This has contributed to increase of agricultural production (Phipps and Park, 2002). However, Phipps and Park (2002) have established that the use of *B. thuringiensis* maize has the added advantage of reducing mycotoxin contamination, thus producing safer grain for both human and animals. In addition, *B. thuringiensis* -maize seeds have been distributed as new improved varieties which give high yields, thus consumers critically address the issue of food insecurity (Oliva et al., 2006).

CONTROVERSY OF GM MAIZE CROP

Regarding the high emphasis placed on innovation of technology in plant breeding especially GM maize crop which has expanded recently, there has been a debate about global food production focusing on GM crops, safety and regulatory approval process of GM crops and foods (Konig et al., 2004; Seralini et al., 2009). Many studies have been documented that, the countries which emphasize use of GM maize crop are often times more concerned about making profit first than health care (Seralini et al., 2014). Some scientists are against GM maize consumption; they have supporting evidence which shows that GM maize affects biodiversity leading to reduction of living organisms in the environment. Scientists are advised to carry out more research works so that they come up with effective conclusion about GM maize (Buiatti et al., 2013). This perspective is similar with Phipps and Park (2002) who stated that the sequencing of genomes provides capacity for selective breeding of crops suited to diverse ecologies including GM maize crop. Whilst scientists continue to debate risks, such as the effects of genetically engineered maize pollen on butterfly populations, drastic reductions in pesticide use achieved through the introduction of GM crops need to be researched (Ortiz et al., 2014). On the other hand, its adverse effects on the environment and human health have not been known for a decade. There are on-going researches which may come up with proper conclusion of whether to use GM maize or not (Buiatti et al., 2013). Spain, one of the countries which have adopted GM maize production technology, has been experiencing European corn borer pest which affects yield (James, 2008). Transgenic imidazolinone resistant maize is resistant to pest leading to the improvement of yield. However, the pest affected areas continue to spread northwards (Park et al., 2011). In other countries, for instance, Poland has allowed GM maize crop where *B. thuringiensis* maize has been commercially grown since 2006. However, other countries are in the first trial; for instance, Tanzania, Malawi, Ghana, and Uganda (Ortiz et al., 2014). The GM maize feed in Tanzania is in restriction awaiting approval from the government (Ortiz et al., 2014). Use of GMO feeds in Poland was permitted occasionally until the year 2012 (Maciejczak and Wąs, 2008). There is on-going debate at different levels regarding introduction of GMO crops in Poland. However, most public opinion shows that half of Polish society does not allow the introduction of GMO cultivations (Maciejczak and Wąs, 2008). *B. thuringiensis* gene, isolated from *B. thuringiensis* bacteria is considered resistance for the transgenesis of maize (Ronald, 2011).

It is assumed that a toxin coded by a bacterial chromosome, after transferring to plant tissues, allows the development of resistance to noxious insects which reduce crops, but have no negative influence on the health of humans and animals consuming the plants (Twardowski, 2010). This procedure proves that, the GM maize is resistant to corn borer (*Pyrausta mirilabilis*), while its commercial variety (MON810) is used for cultivation worldwide, including Poland and other countries of the European Union (Kramkowska et al., 2013). A similar report was documented by Stephenson (2010) that MON810 Monsanto's line of maize was developed through genetic modification to resist corn borer, an insect pest in Europe. Other countries like Spain have planted MON810 without experiencing negative effects (Stephenson, 2010). European Food Safety Authority (EFSA)'s findings indicate that MON810 (Monsanto pesticide produce GM maize) is environmentally safe (Stephenson, 2010). One of the diseases which forced scientists to adopt GM maize crop is the maize streak virus (MSV) of *Zea mays* L. This has made the production of maize in some parts of Africa virtually impossible, leading to critical food insecurity (Bosque-Perez, 2000). Arthur (2011)'s argument is against GM maize crop, because it affects value of maize genetic resources of landraces in the centre of crop diversity. Germany's law allows the banning of a GMO product if it potentially poses harm to the environment. Other countries should adopt the Germany's law to keep the environment useful for other living organisms (Stephenson, 2010). Southern African countries in 2001 rejected GM food aid from the U.S during a severe drought partly due to environmental concern. Scientists generally agreed that the possibility of actual potential environmental risk due to pollen disbursal is extremely remote (Stephenson, 2010).

For GM maize technology to be adopted in a number of countries, unfavourable GMO effects involved the case of

Aventis, the American producer of maize given the utility name of Star Link maize (Kramkowska et al., 2013). The modified plant contained an additional gene, conditioning natural resistance to pesticides (Benbrook, 2012). The transfer of genetic information from *B. thuringiensis* bacteria to the cell nuclei of maize yielded the expression product of Cry9c protein, which produced strong allergic properties (Kramkowska et al., 2013). Due to its specificity, Star Link maize gained the acceptance of the Environmental Protection Agency (EPA) and was permitted to enter the trade market exclusively as an animal fodder (Ramjoue, 2008). However, after commercialization of the transgenic plant, Star Link maize was detected in food products generally accessible in consumer markets (Ramjoue, 2008). In other study with high widespread press coverage, GM Star link maize which was approved for animal feed but not for human consumption was found unsafe for human consumption (Oliva et al., 2006). Spread of the information through mass media was followed by numerous consumers' reports related to symptoms of food allergy in the form of headache, diarrhoea, nausea and vomiting, which were supposed to develop following consumption of products containing the GM maize (Domingo, 2007; Dona and Arvanitoyannis, 2009; Batista and Oliveira, 2009). Before the release of GM maize crop, sufficient research should be conducted such that the recommendation on the use of new GM maize variety should not result in health risk to human, animals and environment in order to prevent biodiversity depletion (Ortiz et al., 2014). Countries which are in trial with GM maize crop should make laws which govern the use of GM maize. This will help to checkmate companies which aim to make profit by selling GM maize without considering the health risk involved (Ortiz et al., 2014).

Other reports are against the findings which emphasize MON810 maize to be safe for human and animal consumption. For instance, Kramkowska et al. (2013) reported harmful influences of MON810 maize (resistant to corn borer) on cells of the pancreas, intestines, liver and kidneys in rodents. Based on several European Union Member States' suggestion of provisional restriction or prohibition of marketing maize MON 810 in their territory, the EFSA GMO Panel concluded that, there is no scientific proof of health risk to human, animal and environment (EFSA, 2012) in using MON 810.

Rossi et al. (2011) noted positive evidence that piglets given maize MON 810 performed better than piglets given the control maize. They suggested that this difference was due to the lower level of fumonisin B1 in the diet. These additional feeding studies are good confirmations that maize MON 810 has no health risk to animals as other recommended maize for animal feed (EFSA, 2012). Results of other studies have shown the effects of different varieties of transgenic maize (MON810 and MON863) on living bodies. They showed that maize producing *B. thuringiensis* toxin is resistant to insects, NK603 and roundup herbicide, which has the potential to induce histopathological lesions first of all in liver and kidneys, and thus, in the principal detoxifying organs (Spiroux de Vendomois et al., 2010). This report has been confirmed in experiments involving two groups of rats: one group fed for 90 days with 11 or 33% components of transgenic maize and the control group which was given non-GM maize. However, Spiroux de Vendomois et al. (2009), in their previous study, suggested that, the chronic toxic effects of GM maize effect should finalized after long term evaluation for at least two years instead of three months.

Studies on similar crop by other authors agreed with previous findings: in South Africa markets, there is a significant reduction in pesticide use due to the availability of GM maize with better resistance to stem borer insect (Chondie and Kebede, 2015). Such varieties include *B. thuringiensis* maize that are already helping farmers in other African countries such as South Africa, Egypt and Burkina Faso (Chondie and Kebede, 2015). The common GM crops of research and commercial interest in Africa are maize, cotton, soybean, pigeon pea, banana, sweet potato and tobacco (Zerbe, 2004). Of these, trials have been conducted in various countries. Though, in Africa, only four countries (Burkina Faso, Egypt, South Africa and Sudan) are growing transgenic crops out of a total of 29 worldwide (Chondie and Kebede, 2015). The policies and legislation in place do not seem to cater for transgenic livestock research and deployment of livestock transgenic animals (Kiome, 2015). The studies on crops like livestock transgenic research in Africa are very weak only in African countries which have practiced transgenic research on livestock. However, no clear information has been displayed (Kiome, 2015). Chondie and Kebede (2015) also suggested that before any interventions be done in the GM crops in African countries, farms must be tested for GM crops by researchers to avoid potential risks. Furthermore, policy makers and researchers should evaluate environmental and socioeconomic risks, for instance, risks to biodiversity, the prospects of insufficient out-crossing distances, the relative absence of clear labelling and other threats to seed purity from adjacent traditional food production. This should be done before farmers change their conventional farming methods to GM (Azadi and Ho, 2010). Research centres must preserve the local landrace strains of maize for food security through seed saving. They should be confined in the gene bank in order to prevent genetic loss and transgenic contamination of the local landraces (Chondie and Kebede, 2015). John and Beringer (2000) believed that GM maize does not present a measurable risk to humans. In addition, the authors do not agree with statement that Novartis should persevere with a crop that is so widely perceived to be a threat to human health (John and Beringer, 2000) and whose construction is so obviously awed from a public point of view. Moreover, there is clear evidence that GM maize is not easily contaminated by mycotoxins such as fumonisin and aflatoxin, toxins produced by fungi that infest maize cobs and which cause serious illnesses in man and animals (DeVilliers and Hoisington, 2011). With the exception of GM cotton, soybean and maize, only a limited number of commercially available GM crops are currently suitable for conditions in developing countries. Even though GM maize crop is promoted for high yield worldwide, Gurian-Sherman (2009) indicated that there is a strong market to grow non-GMO corn for the premiums in Kentucky compared to GM maize product. GM maize crop has contributed to lower its production in the United States (Gurian-Sherman, 2009). In contrast, Lee and Halich (2008) argued that farmers are concerned that they may be losing yield without using GMO hybrids because their finding showed that GMO hybrid yield was higher than the non-GMO sister at a range of 2.5 to 25.5 ratios. More similar studies need to be conducted to compare non-GM maize/GM maize pairs in the future to determine if these differences are consistent across a larger number of hybrids (Lee and Halich, 2008).

For subsistence farmers, for instance in parts of Africa, toxins also cause grave health problems, particularly for children. Mycotoxin contamination of GM maize may be reduced by preventing injuries to maize cobs (DeVilliers and Hoisington, 2011). One among the disadvantages of GMO is the inability of the farmers to save GM maize seed since harvested grains cannot be used as farmer-saved seed. This has been one of the critics of biotechnology which is often given as a reason why in African countries *B. thuringiensis* seeds are not suitable for smallholder farmers who mostly use farmer-saved seeds due to low income (DeVilliers and Hoisington, 2011). Previously, 70% of maize donated to Southern Africa in mid-2002 from United States was GM (Cooke and Downie, 2010). Zambia, along with Zimbabwe, Mozambique, and Malawi refused the food donated and in Zambia, about 18,000 tons of donated maize already in the country was put under security and ultimately transported back after knowing GM maize (Zerbe, 2004). They wanted GM maize which was milled to prevent contamination with domestic maize crop varieties (Cooke and Downie, 2010). On the other hand, Zambia wanted to mill maize to refugee camps that housed some Angolan and Congolese refugees. However, Zambian people were not allowed to consume it (Zerbe, 2004). The analysis of maize varieties collected from farms, household and research centres conducted in Cameroon proved the presence of genetic modified DNA, and probably the source could be from France, United States and South Africa which are the major sources of donated food (Roger and Gone, 2014). A case in point is the new *B. thuringiensis*-maize event called ‘Smartstax’ that was recently registered for environmental release in the USA and Canada (Hilbeck et al., 2011). This GM maize combines six insecticidal *B. thuringiensis*-toxins and resistance genes for two broad-spectrum herbicides. It entered the market with close to no testing for toxic or environmental impacts; it relied entirely on ‘the environmental risk assessment of the individual events’, except for one additional study with an unspecified non-target organism (Hilbeck et al., 2011; DeVilliers and Hoisington, 2011).

HEALTH RISK OF GM MAIZE TO HUMANS AND ANIMALS

Regarding the safety of GM crops and foods for humans’ and animals’ health, a comprehensive review of animal feeding studies of GM crops was found. An equilibrium in the number of research groups suggests that a number of varieties of GM products are mainly maize (Hilbeck et al., 2015). The foreign protein synthesized from the transgene maize has an expected change and interaction in the new environment of a plant cell which may lead to alergenicity (Kosicka-Gębska et al., 2009). This is similar to Star Link maize which has been reported to cause food allergy (Taylor and Tick, 2001). In 2000, there were traces of Star Link maize, a GM maize variety approved for animals feed, but not for human consumption, because most of the consumers reported allergic reactions caused by eating taco shells. These studies were conducted by taking and analysing blood samples from the consumers. It was suggested that further studies be conducted to know if it affects animals (DeVilliers and Hoisington, 2011). According to the studies conducted in 2001 by the Centers for Disease Control and Prevention, there is no evidence that exaggerated people experienced related allergic reaction after consuming Star Link maize (Ramjoue, 2008). From the reported information, there is enough evidence that Star Link maize is associated with risk to human and animals’ health (Taylor and Tick, 2001). The Star Link producer incurred cost to compensate for those farmers who got losses due to the use of Star Link maize. This led to the rapid death of the company (Taylor and Tick, 2001). In order to prevent future problems of this nature, regulation needs to be established to reject GM maize which has not been authorized for animal and human consumption (Kiome, 2015). Other studies have reported long term-effects in rats that consumed two Monsanto products, a GM maize and its associated pesticide, Roundup, together and separately (Spiroux de Vendômois et al., 2009). The target parts of rat affected by GM maize containing Monsanto were liver and kidney (Spiroux de Vendômois et al., 2009). A study showed that rats fed for 2 years with GM glyphosate-tolerant NK603 maize developed cancerous tumors (Seralini et al., 2014). Further studies have reported health risk of some GM maize to animals; for instance, a laboratory experiment was conducted in United States to check for negativity of pollen. It showed that pollen in maize rendered insect resistant through incorporation of a gene coding for a toxin from *B. thuringiensis*. This was toxic to larvae of the monarch butterfly (Losey et al., 1999). Several studies based on one type of toxin have been documented, for instance, Cry1Ab is present in GM maize varieties *B. thuringiensis*11 and MON810. A little is known about the toxicity of other types of *B. thuringiensis* toxin; for example Cry1F, present in the GM maize 1507 (Lang and Vojtech, 2006). Cry1F is highly likely to be toxic to non-target organisms; however, there is need for further studies to confirm it (EFSA, 2011). Most *B. thuringiensis* maize produces toxin from their roots into the soil which is threat to other living organisms in the soil (Flores et al., 2005). The long-term, cumulative effects of growing *B. thuringiensis* maize is toxic to aquatic organisms especially frog larvae and it affect plants which are useful for birds' survival (Zobiole et al., 2011a). Cry1Ab toxin is positive in human as it helps in rapid degradation in the human digestive system (Guimaraes et al., 2010). However, it contradicts recent studies which reported that, there is lack of degradation in the human gut. The toxin seems to have a greater potential to cause allergenic reactions (Guimaraes et al., 2010). This is in agreement with reported information of another recent study which found Cry1Ab *B. thuringiensis* toxin in the blood of pregnant women, and their foetuses showed the possibility of crossing the placental boundary (Aris and Leblanc, 2011).

CONCLUSION

In conclusion, possible costs, benefits and risks associated with particular GM maize crops should be assessed only on a case by case basis. Any of such assessment needs to take into consideration a variety of factors, including the gene or combination of genes being inserted and the nature of the target maize crop. Considering whether GM maize crops should be used or not, it is important to focus on the specific situation in a particular country. All possible health risk to human, animals and environment should be taken into account before releasing new GM maize varieties. The cost-effective, nutrition and the ability to afford an adequate diet should also be considered. Furthermore, research on the use of GM maize crop in developing countries should be sustained and governed by a reasonable application of the precautionary approach. There must be positive scientific results which address the current and future use of GM maize crops. The farmers' perspective and other stakeholders should be taken into consideration on recommendation of GM maize varieties before being publicized.

Conflict of Interests

The authors have not declared any conflict of interests.

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Abbreviations

Bt, *Bacillus thuringensis*; **DDT,** dichlorodiphenyl-trichloroethane; **EFSA,** European Food Safety Authority; **EPA,** Environmental Protection Agency; **EU,** European Union; **GMO,** genetic modified organism; **Ht,** herbicide tolerant; **MRL,** maximum residue levels; **R,** roundup; **USDA,** United States Department of Agriculture

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