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TRENDS, EFFICACY AND OTHER CHALLENGES OF GENETICALLY MODIFIED ORGANISMS (GMOs) IN UGANDA

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Executive Summary

Genetic engineering is a process by which the genetic material carried by an individual cell is altered by the incorporation of foreign (exogenous) DNA into its genome. It is not a haphazard approach to improvement but a new tool requiring much thought and research to identify desirable genes, in regard to what they do, where they can be found and placed into the DNA of a plant to produce a new novel trait. However to ensure consistency and safety, multiple laboratory and field steps are mandatory prior to introduction and commercialization. The goal of genetic engineering is increasing crop productivity and conferment of novel traits such as improved nutritional qualities, delayed fruit ripening, tolerance to different abiotic stresses(temperature, moisture, heat, salinity, herbicide, etc) and biotic stresses (disease, insect-pests, weeds, etc) as well as for studies of plant metabolism. Worldwide, adoption of biotech crops declined slightly in 2019 at 190.4 million hectares from 191.7 million hectares in 2018, while Biotech crops increased 112-fold from 1.7 million hectares in 1996 to 190.4 million hectares in 2019 making biotechnology the fastest adopted crop technology in the world with Biotech soybeans covering 48% of the global biotech crop area. The top five countries (USA, Brazil, Argentina, Canada, and India) planted 91% of the global biotech crop area of 190.4 million hectares. A total of 71 countries adopted biotech crops – 29 countries planted and 42 additional countries imported. On top of more incomes for the GMCs produces, herbicide tolerance technology has also encouraged minimum tillage which reduce green house gas emission into the atmosphere, thereby mitigating the effects of global warming. GMCs have also played a significant role in limiting agro chemicals that are released to the environment through application of BT technology. However, controversies over GMCs potential effects on health, economics, ecology and ethical status of nations, has made their adoption a form of battle field. Though GMC research and development are inherently costly for developing countries to implement, all countries need their local human capacity developed plus adequate local funding from governments to avoid donor driven research and development.

GLOSSARY

Abiotic: Physical rather than biological; not derived from living organisms, eg soils, temperature, rainfall , humidity etc

Biotic: Relating to or resulting from living organisms.

BT: *Bacillus thuringiensis*, a bacterium naturally living in soil
Conventional Plant Breeding: Are classic methodologies of plant breeding, at times referred to as tradition plant breeding practiced based on physical appearance traits

DNA: The molecule inside cells that contains the genetic information responsible for the development and function of an organism. DNA molecules allow this information to be passed from one generation to the next.

HT: Herbicide tolerance

IR crops : Crops with Resistance to specific insect pests (insect resistant or IR crops): here genes have been introduced into crops like maize, cotton and soybeans and make a crop resistant to a particular pest.

Gene: The basic physical and functional unit of heredity

Genetic Engineering: Is a process by which the genetic material carried by an individual cell is altered by the incorporation of foreign (exogenous) DNA into its genome. Can be used interchangeably with Genetic modification, Genetic transformation.

Genetic modification: Altering the genes or DNA of an organism using modern biotechnology techniques.

Genome: The complete set of genes or genetic material present in a cell or organism.

GHG: Greenhouse gas emissions.

Glyphosate: The active ingredient in herbicides that actually kills weeds

GMO: Genetically modified organism

Linkage Drag: the (usually undesirable) effects of genes linked to the genes of interest we are trying to cross to recipient parent in plant breeding

Modern Biotechnology: Breeding Methodologies based on Molecular assisted selection and Genetic Transformation of Crop Plants

Monoculture: The cultivation of a single crop in a given area.

Peer review: This means a report or paper has been subject to independent and anonymous review by specialists in the subject area before acceptance for publication in a journal

Pesticide active ingredient: refers to the amount of substance in a pesticide that is biologically active (and which targets a pest, in the case of an insecticide or a weed, in the case of an herbicide)

Trait: A trait is a desirable or target attribute of a crop such as pest resistance, oil content, drought tolerance etc

Transgene: Transgene describes a segment of DNA containing a gene sequence that has been isolated from one organism and is introduced into a different organism.

1.0 BACKGROUND INFORMATION

Genetic transformation is a process by which the genetic material carried by an individual cell is altered by the incorporation of foreign (exogenous) DNA into its genome. Genetically Modified Crops (GMCs) are the most contentious crop technologies the world faces today. This is because of the advertised benefits in the backdrop of potentially harmful effects on health and environment raised by critics of GMCs which makes this an issue of great concern.

Although contentious, GMCs are made as improved version of the existing varieties and the expectation is that the public would welcome them. Similarly improved conventional varieties are purposefully bred to be accepted by end users. However its common knowledge that at times these new products are received with mixed reactions by the end users. The objectives of this this paper is to critically explore debate on genetically modified crops (GMCs) and suggest a way forward for Uganda. The presentation and content has been deliberately made to appeal to readers with limited background in Genetics, Plant breeding and Biotechnology.

Genetic improvement of crops by conventional means or through genetic engineering is necessitated by the following factors:

a) Ever increasing population on fixed land
b) When yield reaches Plateau level
c) Reduce production costs like weeding
d) Disease and pest
e) Climate change
f) Competition in seed trade
g) Ever increasing population on fixed land (Table 1)

Table 1: Uganda's Population projections by UN in the 30 years

Uganda population growth projection by UN, 1950-2050			
1950	2011	2015	2050
5	33	39	94

Conventional plant breeding involves finding individuals with favorable traits and crossing them with each other, – with the aim that the progeny of the cross will have the favorable traits from both parents. For example, a new crop variety might be bred that is more drought-tolerant or resistant to a certain disease. In reality, however, the progeny have a mix of traits, both good and bad from their parents, and hence it takes a number of breeding cycles to eliminate the negative traits and build on the positive. The final new plant variety then will hopefully have the desired traits inherited from its ancestors along with the associated genes for those traits as demonstrated in Fig 1A.

On the other hand Genetic transformation enables the introduction of foreign genes into crop plants, expeditiously creating new genetically modified crops (GMCs). Genetic transformation can, therefore, be used as a potential tool because it can change the genes of an organism in ways not possible through traditional breeding techniques providing opportunities for new plant varieties (Fig. 1B)

1.1 Genetic Transformation in Plants

The plants, in which a functional foreign gene has been incorporated by any biotechnological methods that generally are not present in the plant, are called transgenic plants or GMOs, GMCs, Boitech or Transgenic crops. When the constructed genes called transgenes are inserted into a new host plants, the plants will be able to express the trait of interest which was not inherently possible in the host plant. The gene of interest may come from another plant of the same or a different species, or a completely unrelated kind of organism like bacteria or animals. BT maize varieties, for example, contain a gene from a bacterium (*Bacillus thuringiensis*) found in the soil that causes the transgenic maize to produce an insecticidal protein that kill insects. The goal of genetic engineering is increasing crop productivity and conferment of novel traits such as improved nutritional qualities, delayed fruit ripening, tolerance to different abiotic stresses (temperature, moisture, heat, salinity, herbicide, etc) and biotic stresses (disease, insect-pests, weeds, etc) as well as for studies of plant metabolism. Transgenic plants with special properties have displaced more than half of the varieties generated by conventional breeding (Godfray *et al.*, 2010).

Conventional Breeding

The Conventional Plant Breeding process introduces a number of genes in the plant. These genes may include the gene responsible for the desired characteristic, as well as genes responsible for unwanted characteristics.

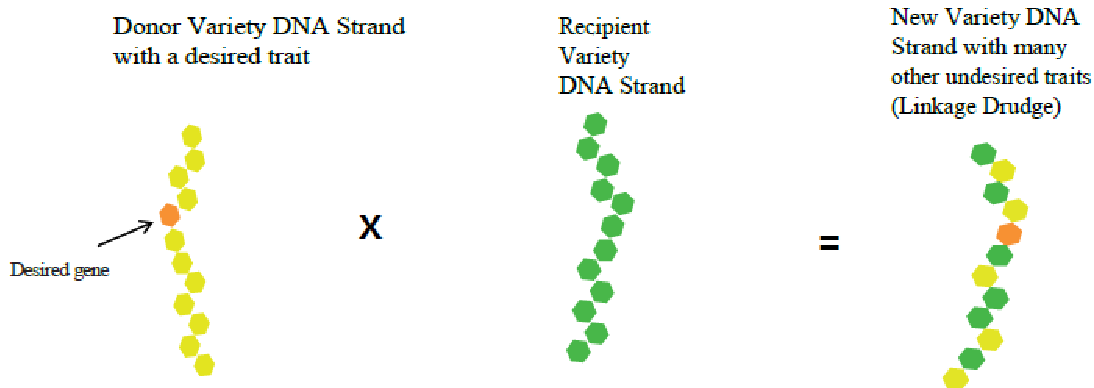

Fig. 1A

Genetic Engineering

Genetic engineering enables the introduction into the plant of the specific gene or genes responsible for the characteristic(s) of interest. By narrowing the introduction to one of a few identified genes, scientists can introduce the desired characteristic without genes responsible for unwanted characteristics as in conventional breeding.

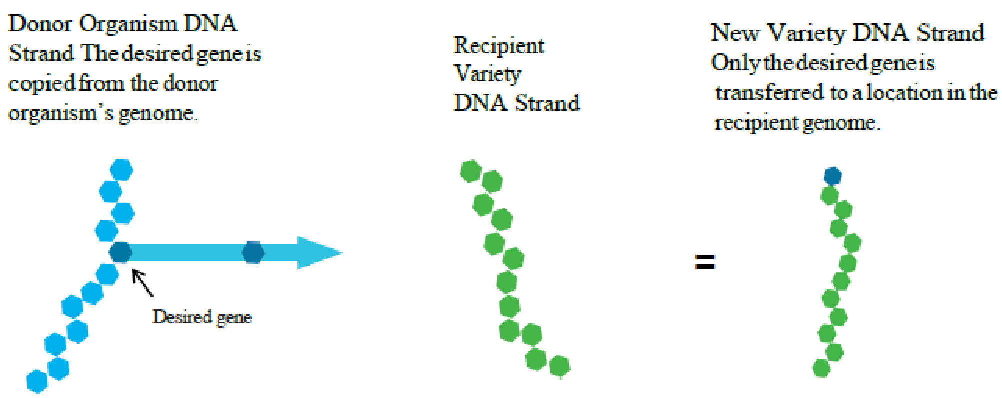

Fig. 1B

Figure 1: Two approaches to developing new Varieties

1.2 Why is it possible for DNA to be transferred between completely unrelated organisms?

This is because DNA of all organisms is made of similar blocks which can easily fit into one another when unpacked and re-arranged using special biotechnology tools and protocols. Genes code (make) for specific proteins and can vary in the way individual DNA components are arranged, but all genes consist of the same subcomponent molecules. Therefore, it is possible to move genetic material between unrelated organisms and have it function in another organism. For example since all DNA are the same and functions the same way, researchers removed the portion of BT DNA that makes a toxic protein and placed it into various plant systems like maize, so that specific insects die when they feed on crops having the BT gene.

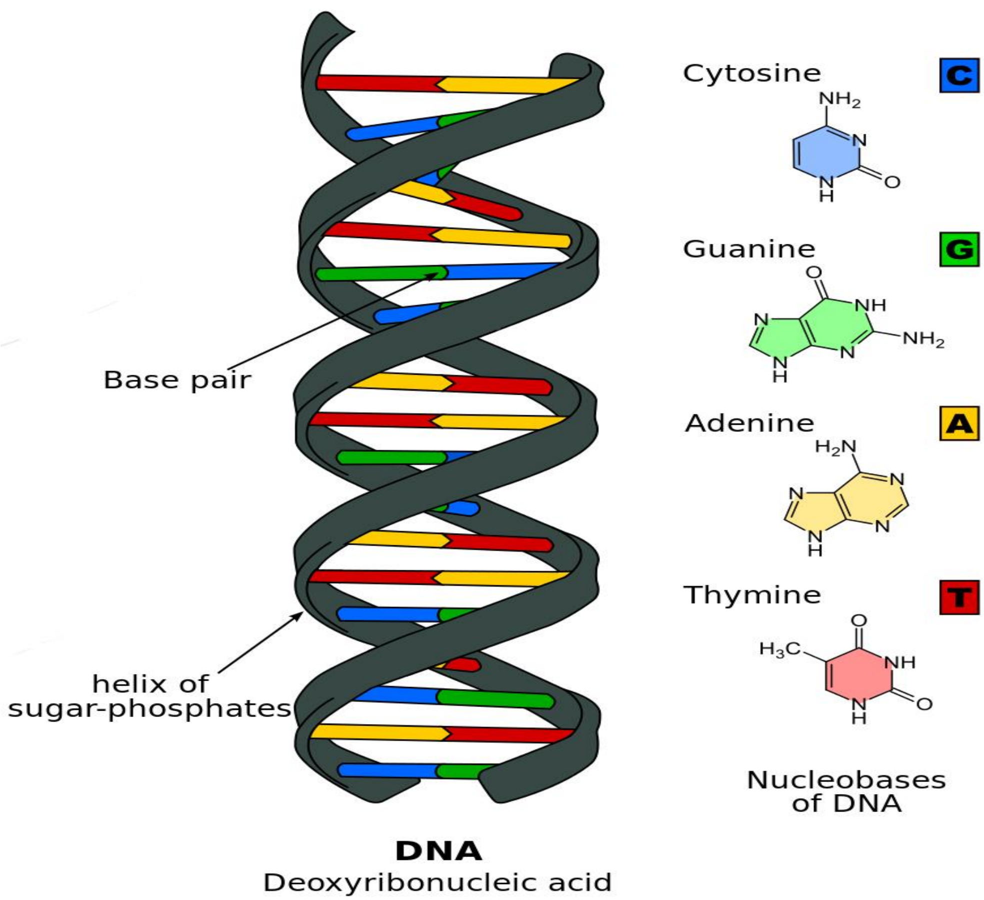

Figure 2: The universal basic structure of DNA for all organisms

1.3 When is it necessary to do genetic engineering?

Laboratory procedures are often a “last resort” approach. Plant breeders still use conventional breeding methods to exchange traits if the trait exists in a compatible plant. For this reason Genetic engineering is carried out if other options of improving the trait of interest cannot work conventionally.

2.0 TRENDS IN GMC ADOPTION

Though the trend of GMC adoption is not consistent in Africa, it’s a different kind of scenario at global level. Worldwide, the most adopted biotech crops were soybeans, maize, cotton, and canola. Soybean was the leading biotech crop with 91.9 million hectares that occupied 48% of the global biotech crop area, with a 4% reduction from 2018. This is followed by maize (60.9 million hectares), cotton (25.7 million hectares), and canola (10.1 million hectares). Based on the global crop area for individual crops, 79% of cotton, 74% of soybeans, 31% of maize, and 27% of canola were biotech crops in 2019 (IAAA, 2019).

Africa: though the trend is not steady, there has been increased awareness and appreciation of GM crops among some African farmers in 2019. Thus, the African continent doubled the number of countries planting biotech crops from three in 2018 to six in 2019. The countries in descending order of biotech crop area are South Africa (2.7 million hectares for maize, soybeans, and cotton), IR/BT cotton in Sudan (236,200 hectares), Malawi (6,000 hectares), Nigeria (700 hectares), Eswatini (401 hectares), and Ethiopia (311 hectares) for a total of 2.9 million hectares, 1.54% of the global biotech crop area of 190.4 million hectares. However, apart from South Africa, the African countries are mainly going in for IR/BT cotton, to control the menace of pests that limit cotton production

The approval of Nigeria’s BT cowpea resistant to pod borers was a major milestone in 2019. Moreover, Kenya approved the commercialization of biotech cotton in 2019 for cultivation in 2020. Other African countries continued to transition from confined field trials to the environmental release phase: Mozambique for drought tolerant maize and Kenya for BT maize and cassava brown streak disease resistant cassava. The countries that improved their biosafety regulation to facilitate biotech crop development and adoption are Ghana and Niger. A number of countries also endorsed the trade of biotech crops and guaranteed for their food safety including Zambia (IAAA). At least 8 countries have in Africa (South Africa, Swatine, Malawi, Kenya, Sudan, Nigeria, Ghana and Bukina Faso have approved commercial release of GMCs in their countries) (ABNE, 2020). Other 15 countries including Uganda have got Biosafety frame work for GMCs (Figure 3).

Figure 3: Countries growing GMCs in Africa

3.0 EFFICACY OF GMCS

Genetic engineering works and has demonstrated the ability to produce a desired or intended result in the crops trait of interest. There 71 countries that have adopted biotech crops, where 29 countries have planted the crops while 42 additional countries imported GMCs (IAAA, 2019). The big five successful Biotech crops have been insect resistance, delayed fruit ripening, nutrition enhancement, herbicide tolerance and virus resistance. The following are some the most successful GMC technologies:

3.1 BT Technology for protection against Insect

BT stands for the naturally occurring bacterium *Bacillus thuringiensis*, which lives in the soil and is found all over the world. BT genes have been introduced into crops like maize, cotton and soybeans to make a crop resistant to specific pests (Figure 4). Such crops are known as insect resistant or IR crops. BT produces a protein crystal that binds to receptors on the stomach wall of certain insects, and then it penetrates creating holes. The holes allow gut bacteria and other contents to spread throughout the larva, usually killing it within 24 to 48 hours. BT is harmless to mammals, birds, fish and other organisms, which neither have the BT receptors nor the alkaline stomach conditions BT needs for activation.

Figure 4:

Comparing BT protected maize with unprotected maize on the extreme left

3.2 Virus disease protection

Genetic engineering has made some plants tolerant to virus diseases through a process called Pathogen-Derived Resistance (PDR) which is similar to vaccinations in human. PDR utilizes a gene or a portion of a gene of the virus of concern. This incorporated viral gene allows the engineered plant to recognize the virus when it enters into the plant tissue and disrupts the viral infection process providing protection against that specific virus. This method saved the Hawaiian papaya industry from the papaya ring spot virus (Figure 5).

Figure 5: GMC Papaya on the left with unprotected papaya on the right

3.3 Herbicide Tolerance Technology

The technology allows a herbicide to be used to target weeds in the crop without harming the crop (Figure 6). For example, a glyphosate tolerant crop is tolerant to the herbicide glyphosate. The benefits largely derive from more cost effective (less expensive) and easier weed control for farmers. Most users of this technology in the canola, soybean and maize derive higher yields from better weed control (compared to weed control obtained from conventional technology), resulting in an extra tons and income with HT technologies. Compared to other herbicides, glyphosate is potentially less toxic to other organisms.

Figure 6: The burden of weeds (left) and how HT tolerant technology works in soybeans, saves labor, time and cost (right)

3.4 Enhanced Color and nutrition

Golden rice has a golden yellow color due to increased beta-carotene (Figure 7), a precursor of vitamin A, critical for healthy vision and often lacking in diets of people living in developing countries where rice is the main staple starch. The donor DNA was inserted into rice DNA and the rice interprets the added DNA, resulting in increased beta-carotene production in the grain providing an inexpensive and readily available source of Vitamin A.

Figure 7. Conventional rice (foreground) and second generation golden rice (background). Photo courtesy of the International Rice Institute.

4.0 DEBATE ON GENETICALLY MODIFIED CROPS

The debate on GMCs is generally concerned with the potential positive or negative impact on the environment, food, control, Ethics and economic control.

4.1 The Promise of GMCS

On the Environment: Intensive crop farming requires large inputs of oil, fertilizers, pesticides which collectively are major contributors to climate change. Use of Biofuels (Product of GMCs) would go a long way in reducing depence on oil. World over, GMCs are being grown for agro-fuel production with 70% of total GM Soya grown for this purpose only. Bio-fuels are believed to be a cleaner fuel with lower emissions and a befitting alternative to fossil fuels Brookes G (2016).
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According to IAAA 2019, BT Technology saves crop growers from applying pesticides and increases yield and quality because there is less insect damage to crop resulting in higher yields while at the same time keeping the environment (Table 2).

Table 2: Positive effects on the environment of using GMCs in the period 1996 - 2018

Period	Chemicals saved from being released into environment (million kgs)	Percent saving of on chemical use by farmers	Percent reduction of negative impact on environment (environment impact quotient)
1996-2018	776	8.3	18.3
2018	51.7	8.6	19

Increased Carbon Retention: Since man started agriculture, plowing has been a process of aerating the soil, to integrate organic matter and release large amount of carbon gases trapped. However, GMCs are considered as no-till crops which in turn decrease the carbon lost during tillage. In this way, these crops can increase retention of carbon and further bring down green house gas (GHG) emissions (Brookes, 2016). .

Climate-Ready Crops: Apart from these indirect benefits, some GMCs are made to be climate proof to bear the environmental stress in changing climate such as droughts and floods. In some cases, both direct and indirect benefits can also be looked upon from GMCs like the bioengineered nitrogen fixing crops (including cereals) which are expected to increase the nitrogen use efficiency as well as reduce our dependence on fossil fuel based nitrogen fertilizers. It also helps to reduce GHG emissions and water pollution due to leaked nitrogen products (Brookes,2016). .

Genetically Engineered Trees: Genetically engineered trees are also being developed for a range of uses. In China, Popular species have been genetically engineered, cloned and planted on commercial scale to prevent soil erosion [14]. These fast growing trees fix more CO_2 and produce more cellulose for industrial use than conventional trees and appear as a very attractive option (Brookes, 2016). .

Cuts on Greenhouse gas emission: GM crops have also delivered significant savings in greenhouse gas (GHG) emissions. At a global level this derives from two principles sources: Reduced fuel use from less frequent insecticide applications and/or a reduction in the energy use in soil cultivation. The fuel savings associated with making fewer spray runs (relative to conventional crops) and the switch to conservation, reduced and no-tillage farming systems have resulted in better savings in CO_2 emissions.

The use of ‘no-till’ and ‘reduced-till’ farming systems. These production systems have increased significantly with the adoption of GM HT crops because the HT technology has improved farmers ability to control competing weeds, reducing the need to partly rely on soil cultivation and seedbed preparation as means to getting good levels of weed control. As a result, tractor fuel use use for tillage is reduced, soil quality is enhanced and levels of soil erosion cut, leading to lower

GHG emissions from soil. These soil-based GHG emission savings have occurred mostly in North and South America and mainly associated with corn and soybean crop production systems (Graham Brookes)

4.2 The Concerns over GMCs

The inherent power of GMCs, which can go a long way in serving mankind, is not doubtful. However, controversies over its impact on health, economic, ecological and ethical implications, mar its role in serving mankind in any possible way.

On the basis of above insight into both the contentious issues on GMCs, their impact is highly uncertain and unsettled. Lack of factual scientific data, absence of post commercial cultivation monitoring, misrepresented data, wrongful interpretation and modification of existing information, together generate massive asymmetrical knowledge base (Amanpree et al. 2013).

Misinformation of Data: It's alleged that Data presented by proponents of GMCs is highly exaggerated. The direct and indirect impacts of these crops on human health, ecology and environment remain to be evaluated and hence, GMCs today still stand at the crossroads of acceptance. However anti GMCs movement is also known for producing clearly exaggerated information that is not peer reviewed but with the intention of provoking fear for GMCs as exemplified in Fig 8.

Figure 8: images of maize and potatoes made to intentionally provide fear of GMCs among consumers

Patents: GMCs technologies are economic driven and are based on wishful benefits for developing countries whose regulatory capacities are wanting. Until economic concerns remain the main driving force behind GMC technologies, drawing any real, remarkable gains from them appears impossible especially for the less developed countries. Despite claims and counter claims on the pretension of GMCs as solution to world food insecurities, a large number of biotech companies around the world patent all the Biotech genes of interest. In short the GMCs are not free.

Effects on non-target species: There is a possibility of untargeted species being harmed by BT transgenic crops. Concerns have been raised regarding adverse effects on Monarch butterfly and other insect populations, which are not the original target of the BT technology. BT toxins kill many species of insect larvae. Therefore, addition of BT genes to plants could also have serious consequences on other unintended insect pests since their feeding is random (Prakash et al., 2011;Verma et al., 2011).

Gene transfer to wild or weedy relatives: Novel genes placed in crops will not necessarily stay in agricultural fields. If relatives of the altered crops are growing near the field, the new gene can easily move via pollen into those plants. The new traits might confer on wild or weedy relatives of crop plants the ability to thrive in unwanted places, making them super weeds as defined above. For example, a gene changing the oil composition of a crop might move into nearby weedy relatives in which the new oil composition would enable the seeds to survive the winter. Overwintering might allow the plant to become a weed or might intensify weedy properties it already possesses. However the major consequences of this is damaging the integrity of the original biodiversity

Health concerns of GMOs: Human health concerns have arisen over the possible long-term effects that may arise from the bringing together of gene combinations not occurring naturally in the environment. In particular, concern has been expressed at the possibility that GM foods may be more toxic or carcinogenic compared to food derived from conventionally produced crops. The issue of transgenes surviving digestion and establishing or recombining with genes in the host genome, especially in the gut microflora, has also been raised.
The use of antibiotic resistance marker genes in plant genetic modification has given rise to concerns about the possible risk to human health due to these genes decreasing the effectiveness of prescribed antibiotics through the establishment of antibiotic effects in the food chain. The possibility of increasing and unpredictable exposure to allergens and toxins through new gene combinations has also given cause for concern. These concerns also relate to animals through the consumption of GM derived animal feed and the possibility that such harmful impacts could subsequently be transferred to humans who consume such animal products (Hug, 2008).

Ethical and economic issues: Intellectual Property Rights (IPR) are one of the important factors in the current debate of GMCs. The GMCs are patented by Agribusiness companies leading to monopolization of the global agricultural food and controlling distribution of the world food supply Amanpree et al. 2013. Social activists believe that the hidden reason why biotech companies are eager to produce transgenic crops is because they can be privatized, unlike ordinary crops which are the natural property of all humanity. It is argued that to achieve this monopoly, large companies take over small seed companies to become the biggest agribiotech corporations in the world.

Lack of adequate legal capacity and regulatory frame work: Most developing countries lack adequate capacity to monitor, assess and control activities involving GMCs. This challenge can be addressed through deliberate support to government agencies and allocating adequate finance to research and agriculture. It is the responsibility of the government to educate the masses basing on evidence based information (Amanpree et al. 2013).

Monoculture, Mixed cropping system and Co-existence: GMC is monoculture based, more suited to large land holders. However in developing countries where, 80% of farmers have marginal and small land holdings of less than 2 ha, GMC may not augur well. As they grow a variety of crops together and cannot afford to leave large isolation distances as a pre-requisite in GMC cultivation. Performance of GMCs varies with region, cultural practices, agro climatic conditions and geographical conditions. Co-existence of GMCs and conventional crops becomes a very big problem here (Amanpree et al. 2013).

More Concerns : Some of the adverse effects attributed to GMCs include new allergens in food supply, antibiotic resistance, production of new toxins, concentration of toxic metals, enhancement of the environment for toxic fungi to grow, increased cancer risks, degradation of the nutritional food value, and other unknown risks that may arise later (Amanpree et al. 2013).
On nitrogen fixing GMCs, it is said that there has been very little progress in terms of developing real tangible products. Moreover such modification requires major changes in plant metabolism. Its interactions with the agro-ecosystem are unknown. It is a known fact that no seed can germinate in complete absence of moisture. Thus development of a drought resistant crop appears to be relatively impractical.

5.0 RATIONALIZING GMOS FOR UGANDA

We need to adopt GMCs on case by case basis, following the principles of participation and inclusion of all stakeholders. The critics GMCs movements generally use scaremongering approaches and should be willing to engage along the reason of Science. Those promoting adoption of GMCs should present the technologies as they are but not as silver bullets which will solve all the current challenges. I suggest a deliberate move by Uganda to adopt GMCs from an informed point of view where all parties have given views on the subject matter: Table 3 shows a case by case basis suggestion for adoption of GMCs in Uganda.

Table 3: Proposed case by case consideration of Ugandan crops for Genetic Engineering

Crops	Characteristics	Justification for GE
Beans	Self-pollinated Easy to control pollination Major household food crop	Participatory GE Only for killer traits'
Soybean	RR traits to expire	Participatory GE The trait is off patent 60% production costs goes on weeding
Bananas,	Propagated by cuttings Cross pollination does not pose a challenge	Participatory GE
Cassava, Sweet potatoes	Propagated by cuttings Some genotypes flower while others don't	Participatory GE for varieties that don't flower

	Compatible wild relatives	
Potatoes (Irish)	Propagated by cuttings Some genotypes flower while others don't Have deadly diseases such as bacterial wilt that have challenged all control measures Prone to volunteer plants	Participatory GE for varieties that don't flower and poor at producing volunteer plants
Sunflower	Highly out crossing Purely for oil and feeds	Participatory GE
Maize	Very out-crossing, Produced by on so many small plots Major household food	GE at Research level Difficult to control pollination and regulate co-existence of the very many small plots
Sorghum	Significant Out Crossing Major household food	No GE Compatible wild relatives
Millet	Significant Out Crossing Major household food	No GE Compatible wild relatives

5.1 What needs to be done Uganda:

a) Fight corruption
b) Commit 10% to Agriculture according to Maputo declaration
c) Support Research locally
d) Appreciate and invest the raw materials for making GMOs. ie local land races and other genetic resources through protection and conservation using our own resources.
e) Develop capacity in Biotech and Bio-prospecting
f) Take advantage of expired patents and use them to make our own GMCs
g) Strengthen regulation in Uganda to avoid
    - Fake seed on market
    - Food safety concerns, afalatoxins and chemicals and Kavera every where
h) Regulate against Counterfeit and junk products on the market
i) Deliberately invest money into research based on local research agenda
j) Pass the Biotechnology and Biosafety Bill to give the nation proper direction

5.2 Concluding Remarks

- GMCs clearly work but works differently for different countries

- It is not always necessary to develop GMCs.

- While GMCs are very beneficial in appropriate situations, they cannot serve as a silver bullet to all the agricultural challenges faced in a given nation

- **GMCs are not stand-alone technology. There are other enabling policies which must go hand in hand with GMC technologies. For example plant variety protection and enforcement of regulations to ensure quality seed standards. If these regulations are not in place, GMCs seed may do more harm than good.**

- If we can't make progress with conventional technologies in Agriculture at present, we will also make it with GMCs, because developed countries developed with conventional technologies first

- Though GMC research and development are inherently costly for developing countries to implement, all countries need their local human capacity developed plus adequate local funding from governments to avoid donor driven research and development.

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Independent research by government agencies becomes difficult because of huge investment involved and lack of information and technological exchange. Further it is very expensive and difficult to prove the safety of GMCs in the light of various claims of biotech giant which some NGOs and scientists term as misguiding and misleading [17].