Title: GMOs in Africa: Opportunities and Challenges in South Africa

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Abstract

Genetically modified organisms are expected to have a large impact on the ability of humanity to feed, fuel and heal itself in light of the growing global change, and adverse geo-climatic conditions anticipated as a result of climate change. GMOs have already demonstrated potential in enhancing food production, with additional benefits in quality of crops and environmental aspects. South Africa is one of the few developing countries that have joined an increasing number of countries that have commercialised GM crops. With South Africa being an early adopter of GM technology, the economic benefits for some of the crop technologies can be readily demonstrated, particularly in commercial crop production. Seventy five percent of agricultural output comes from the highly organised commercial sector, and small scale farmers contribute the rest. Malnutrition and food insecurity remain an issue in this seemingly prosperous economy. In this paper we examine the progress made in the adoption of GMO crops, the potential of the technology to meet the millennium targets of food security and poverty alleviation, and the hurdles that this technology faces in South Africa.

Agriculture in South Africa

South Africa has a dual agricultural economy, with a well-developed commercial sector and a reasonably big subsistence sector. Approximately 12% of the surface area can be used for crop production, and high-potential arable land comprises only 22% of total arable land with about 1.3 million hectares (ha) are under irrigation. Agricultural activities range from intensive crop production and mixed farming to cattle ranching in the bushveld, and sheep farming in the more arid regions. Primary agriculture contributes about 8% to formal employment and 4.5% to the gross domestic product (GDP) of South Africa. However, there are strong linkages into the economy, so that the agro-industrial sector comprises about 12% of GDP. Commercial agriculture is for the most part highly organised, and a technology driven large scale sector that is at par with many developed countries, and this system delivers GM, non GM and organic crops. The choice of crop to be produced is up to the farmers. Crop production focuses largely on maize, soy bean, wheat and cotton. The viticulture and horticultural sectors have a strong export orientation, with Europe being a key destination for South African produce. Thus introduction of GM products in these sectors may impact heavily on the export market. There is also a sector of small scale and emerging new farmers who have recently acquired land through government that formally belonged to the largely white owned commercial sector, who will need to grasp new

technologies in order to maintain and enhance crop production. It is against this background that we review the progress and challenges in the adoption of GMOs.

The promise for GM technologies in South Africa

The country recognizes the potential of genetic modification as a technology that can contribute significantly to national crop production, impacting positively on food security, income generation and poverty alleviation particularly for the resource poor farmers. Poverty alleviation is a key objective of the millennium development goals. Other possible positive outcomes of the use of GM technologies include a safer environment that is conducive to sustainable agriculture and other aspects in health. Genetically modified crops have been around for more than two decades, and it is almost a decade and a half since the release of the first commercially cultivated genetically modified crops. Globally, the hectarage of GM crops has grown from almost nothing in 1996 to more than 140 million hectares in 2009 (Clive James, 2010). South Africa is one of the early adopters in the continent, and GM cotton was first cultivated in 1997. South Africa is seen as a leader in the African context when it comes to GM crop production, and globally, it is amongst the top eight countries, growing a total of 2.1 million hectares of GM crops; 98% of cotton, 85% is soybean and 78% of both white and yellow maize grown are genetically modified (ISAAA, 2009 Report).

Economic Benefits of GM Technology

To date, South Africa is the fastest adopter of GM crops in Africa (James, 2009) The steady increase in area under GM crops in South Africa reflects the confidence that the farmers have in the technology. According to Agri-SA, the cumulative value of GM maize at farmer's price totalled R21.63 billion, and that cumulative GM maize production was 14.67 metric tons, with the added benefit from a 10.6%yield increase amounting to an estimated R2 billion by 2008. There are numerous reasons why these crops were embraced, with the initial notable benefit upon adoption being higher yields that increased farm profitability for both small scale and large scale farms by up to $506.9 million (Kirsten and Gouse, 2006; Keetch et al., 2005;). High farm profits are important for the country as a whole as agriculture accounts 4.5% to the country's gross domestic product (www.nda.agric.za). Less damage to the crops contributes to the higher yields and also increases the quality of the food which is largely beneficial to the consumers (Keetch et al., 2005; Brookes and Barfoot, 2010). The most popular trait in South Africa is Bt insect tolerant maize, followed by herbicide tolerant maize. The sale of stacked trait crops with Bt and herbicide resistance commenced in 2007. GM maize has been consumed by South Africans without any adverse effects reported on

human health. Field trials with drought tolerant maize are currently under way in South Africa.

Health Benefits

There are also indirect health benefits enjoyed by the consumers as a result of the adoption of GM crops. While these benefits are as yet not quantified, research evidence is currently indicating that GM maize has lower levels of cancer causing agents such as mycotoxins, in comparison to conventional and organic maize (EuropaBio p8; Gomez-Barbero et al., 2008). GM technology has also significantly contributed to a reduced use of insecticide and herbicide, with up to 33% reduction in levels observed in South Africa (ref). This is particularly important for the local farming communities as unfortunately, numerous cases of human poisonings have been reported due to pesticides' environmental pollution, with pesticides often finding their way into water courses, (Betz et al., 2000; Wilkins et al., 2000; Yousefi, 2000).

Environmental Benefits

In a global study done by Brookes and Barfort, it was observed that less need for frequent insecticide and herbicide spraying, and new farming systems accelerated by GM technology, have resulted in less fuel usages which consequently reduces the amount of carbon dioxide released into the atmosphere. With the concerns about climate change escalating, this is an important environmental gain. This is an important contribution to lowering green house gas emissions, and an important contribution to the *Millennium Development Goals.* It is important to note that although the GM technology results in less spraying, high yields in a smaller area and cleaner crops, the adoption of GMOs has no impact in the amount of farm labour employed (Gomez-Barbero and Rodriguez-Cerezo, 2007). More benefits are provided by the technology even outside the food production industry.

Challenges to GM Crop Production in South Africa

Despite the early adoption of GM technology by South Africa, and the substantial increase in hectarage planted under GM crops, there are significant challenges to the production of GM crops. The GM crop debate continues to rage on, with non-governmental organisations opposed to the use of this technology, growing from strength to strength.

The Regulatory Environment

South Africa has a functional regulatory law, policy framework and infrastructure that have facilitated the commercial release of numerous traits in maize, cotton and soybean. All activities involving GMOs in South Africa are administered by the Directorate Biosafety of the Department of Agriculture, Forestry and Fisheries (DAFF) under the regulation of the Genetically Modified Organisms Act, 1997 (Act No. 15 of 1997). The Directorate Biosafety has the following core functions:

- Development and implementation of policies and strategies;
- Provision of technical advice on matters pertaining to GMOs;
- Facilitation of a compliance system for assessing risk associated with the application of GMOs and;
- Provision of an administrative support system for bodies established under the GMO Act.

The GMO Act makes provision for the appointment of a Registrar, two regulatory bodies and inspectors. The two regulatory bodies are the Advisory Committee (AC) and the Executive Council (EC). The Advisory Committee consists of an expert panel of scientists which is constituted to conduct a scientific evaluation of the risk assessment made by an applicant for a GMO permit. The recommendation made by the AC is then passed on to the EC. The EC is represented by officials from various government departments who make a decision whether to approve or not, a GMO activity. The scientific recommendations as well as socio-economic factors are considered in this decision. GMO activities that are approved are regulated by means of permits issued by the Registrar of the GMO Act. Compliance of the permit regulations is monitored by the Inspectorate of the DAFF.

Additionally, the Cartegena Protocol for Biosafety is an international agreement that was established under the Convention of Biological Diversity for the safe transfer, handling and use of living modifies organisms (LMOs) resulting from modern biotechnology. South Africa acceded to the Cartegena Protocol in August 2003 and, in order to ensure effective streamlining of the regulatory process, had to undertake an amendment of the GMO Act, which resulted in the GMO Amendment Act, 2006 (Act No. 23 of 2006).

The Directorate Biosafety sees its responsibility as being to “Objectively evaluate the scientific evidence, on a case by case basis and make decisions relating to GMO activities in the best interest of the environment, human & animal health.”

(www.pub.ac.za/ppt/gmos_perspective.ppt). The South African Biosafety Clearing House (BCH) is also the responsibility of the DAFF. It has been established as per Article 20 of the Cartagena Protocol on Biosafety, in order to facilitate the exchange of scientific, technical environmental and legal information on living modified organisms (LMOs). The Biosafety Clearing House (BCH) is an information exchange mechanism established to assist Parties to implement its provisions and to facilitate sharing of information on, and experience with, LMOs (http://www.daff.gov.za/). The South African BCH web portal is in the final stages of development.

South Africa is unique, as it is the only African country that has produced GM crops for more than 10 years and also has functional GMO laws and policies which regulate the production, import and export, and handling of GMOs. However, as GM crop production increases in South Africa, and with political and market conditions changing, the management of the marketing and trade of GM crops continues to change and the country's regulatory system is now facing challenges related to the import, export and marketing of these crops (Gruère and Sengupta, 2009). South Africa is also unusual in that it produces and exports both GM and non GM food products, maintaining a parallel production line for them both.

An important challenge encountered in South Africa is that although there are guidelines of what data is expected to be included in the regulatory dossier, it is not always clear what specific data needs to be submitted to Registrar of the GMO act. This leaves the applicant open to many risks as data can be demanded that may require an additional few years to generate. If the applicant knew beforehand that a specific set of data was needed they could have generated this during the development phase. The regulators also seem reticent to interact with applicants and give them clear guidance on what data would be required from them. This leaves the applicant with the quandary of perhaps doing too much research which is a waste of time and money, or doing too little which can also be costly. It would be ideal if the applicant knew exactly what the minimum requirements were to get approval. This is especially true regarding the requirements for the socio-economic impact assessment. There is also no clarity on whether an actual practical study has to be conducted, or merely a desktop study.

Until recently, the AC and the EC only had to review data of applications for GMO releases that had been deregulated or approved elsewhere. GMOs are beginning to come through the research pipeline with locally developed traits that have not been assessed anywhere else, which will also compound the burden placed on the South African regulators. If it was found later that these events cause harm, the implications for the regulators could be dire. If such events were given the go-ahead, there may be repercussions down the line if these

events were found in shipments destined for Europe and elsewhere, where these events may not have been approved. Europe, a major destination for South African agricultural products, has a zero tolerance approach for non-approved events in Europe.

To complicate matters further, crops which originated in Africa are also being transformed with events to improve the food-quality of these crops (e.g. sorghum), in order to alleviate malnutrition. Here again the regulators will be faced with the dilemma of the potential benefit for communities weighed up against the potential impact on the environment.

An additional challenge faced by product developers is the decision making process, which can be fairly slow. A reason for this could be that the decision making body (the EC) consists of appointed officials who already hold full time jobs; making their workload unsustainable. Going forward it might be better for all parties concerned, to appoint full time EC members, as the number of applications increase as well as the increasing complexity of some of the new applications.

Anti-GMO lobbyists are also increasingly placing pressure on the regulators to deny applications for contained release as well as general release. Virtually all applications are opposed by these groups.

As a result of these pressures the regulatory procedures are becoming increasingly tight, effectively slowing down decisions and therefore potential adoption of new products.

Monitoring

Monitoring is a key component of the regulatory environment. The South African government has made efforts in implementing a monitoring framework for the assessment of pre-release and post commercial GMOs by amending section 78 of the National Environmental Management: Biodiversity Act (NEMBA) to ensure that the environment is protected from the risks that could potentially arise from GMOs. The pre-release monitoring is done by the Department of Agriculture, Forestry and Fisheries (DAFF). However the post commercial general monitoring is currently mandated to the South African National Biodiversity Institute (SANBI). SANBI's mandate states: (we) "must monitor and report regularly to the Minister on the environmental impacts of all categories of genetically modified organisms, post commercial release, based on research that identifies and evaluates risk". Furthermore, SANBI has been mandated "to develop a monitoring programme suited to a South African environment and farming culture". One such way is to utilize structured risk analysis tools and stakeholder involvement to determine the most

relevant biodiversity monitoring endpoints. In addition, SANBI is conducting South African-specific research on GMOs and their potential impacts on the environment. This information will address knowledge gaps and contribute to building capacity related to biodiversity, GMOs and biosafety"

(http://www.sanbi.org/index.php?option=com_content&view=article&id=183:research-science&catid=82:applied-biodiversity-research&Itemid=798). This poses a challenge to the monitoring system because it means that resources are limited, and this is supported by the current monitoring of only one crop (MON810) out of the 129 traits being grown in South Africa; clearly more resources are required. Another challenge in the monitoring system is the shortage of trained biodiversity experts in South Africa.

Development and Stewardship of GM crops

The three GM crops being cultivated in South Africa are maize (white and yellow), cotton and soy beans. These have all been developed and marketed by large multi-national corporations. Due to the high cost of developing GM crops these companies have naturally concentrated on products that will give them a return on investment. These companies have the means to market, distribute and monitor their products. This has allowed publicly funded research groups to concentrate their research on the so-called orphan crops, and to look at traits such as nutritional enhancement. However, this poses additional challenges as these organisations do not necessarily have the expertise and capacity to commercialise these products developed by their research. Development of a regulatory dossier to present to the regulators when applying for a general release permit is very costly. The potential benefits compared to the cost of development would have to be carefully weighed up by institutions willing to provide funding for this step. The product would also have to be marketed and distributed by a third party which has this capability. Post market stewardship then also becomes an issue for the developer of the product which also raises the question of liability and redress if problems arise. There will obviously not be one solution to these challenges as each crop and trait will be unique and require a unique solution.

Many of the agricultural industries do not have a system for segregation or identity preservation. This poses an interesting dilemma, does one first develop an identity preservation system and then release the GM product, or vice versa? An application in 2009 for the general release of a GM potato that is resistant to potato tuber moth (PTM) by the Agricultural Research Council (ARC) was declined. One of the reasons listed by the EC was that there was not an identity preservation system for segregating GM and non-GM potatoes in South Africa.
(http://www.nda.agric.za/doaDev/sideMenu/biosafety/doc/ECminutes21July2009.pdf).

This poses two questions; firstly - Is it necessary to have segregation (this is not currently a requirement for any other GM crops on the market) and secondly, who would be responsible for setting up this system and regulating it? As yet, these questions remain unanswered.

Other Challenges

Socio economic issues

Most African food exports are to Europe and Asia, for instance, where GM foods are widely regarded as 'Frankenstein foods' and shunned by consumers. Some European countries request verification from exporting countries that their beef is not fed with genetically modified maize. This places the onus on exporting countries to develop an appropriate labelling and traceability system, and such a system is being developed in South Africa (http://soer.deat.gov.za/521.html). Despite the fundamental challenge that faces African countries, that is, how to interpret the available contradictory information because much information is oversimplified and may focus on a single aspect of the GMO debate (www.eoearth.org), it has been noted by South Africa's department of environmental affairs that most other countries on the continent, however, do not have the legislation or the capacity to implement such a system. Furthermore, if GM foods are introduced into exporting countries without the required labelling and traceability support, grain and beef exports to Europe and Asia could be rejected, with dire potential economic consequences. Labelling itself has cost implications that may effectively impact on the gains made through adoption of the technology (http://soer.deat.gov.za/521.html).

The anti-GM Movement

The anti-GM Movement consists of a number of small organizations that work together to form a united front. One of the strategies used to make their presence appear larger is to make use of petitions signed by the public, and to present these to various forums. Some of the better known organisations are: South African Freeze Alliance on Genetic Engineering (SAFeAGE), The African Centre for Biosafety (ACB), Earthlife Africa (ELA) and Biowatch South Africa. Greenpeace South Africa has also recently been established.

One of the objectives of The African Centre for Biosafety, which is one of the more active anti-GMO lobby groups, is:

"To contribute to the creation and implementation of comprehensive and stringent biosafety policies, legislation and procedures on the African continent and in so doing, oppose

commercialisation of GM crops in Africa specifically, and the application of transgenic technologies, generally." The implication is that ACB wants to use the regulatory system to stop the use of GM crops, not to regulate their safe use.

Some of the issues raised by the anti-GM lobby are: the safety of the GM crops for consumers, the impact of GM crops on the environment and biodiversity, the lack of choice by consumers (labelling of products) and potential negative socio-economic impacts.

Funding for Agricultural Biotechnology Research

Limited funding for agricultural biotechnology research was also noted as a major hurdle to South Africa's increased participation in the industry. Much of the agricultural biotechnology research has been funded by international donor organisations (e.g. USAID) or crop specific industry organisations (e.g. wine industry).

Farmer Education

Farmer education on the benefits of the technology is an essential to facilitate the adoption of GM technologies particularly by the emergent farmers in South Africa. Basic agricultural knowledge and good agricultural practices are essential before the GM technology could help. Basic extension services in South Africa are provided by the provincial departments of agriculture. AfricaBio is an independent, non-profit biotechnology stakeholders association. Their key role is to provide accurate information and create awareness, understanding as well as knowledge on biotechnology and biosafety in South Africa and the African region.

They have been working on successful white maize demonstration trials in collaboration with emergent small scale farmers over the past seven years. Reportedly, the trials, conducted by AfricaBio in conjunction with regional government departments and farmer education organisations, recorded average yield increases of over 20%, and went some way to secure a sustainable food supply for emergent farmers.

In the example of the GM potato developed by the ARC another reason for declining the application was that "the capacity of small scale farmers to implement risk management measures could potentially be onerous". Many of the crops developed by the public sector are aimed at these same small scale farmers. Would this then imply that none of these crops would get approval or that there would have to be special training for these farmers? This will be almost impossible for the developers and would have to be done through the formal extension services. Of course the question also comes to mind; how do the small scale

farmers manage to cope with the risk management measures of the crops currently on the market?

Regional Trade and Harmonisation

In a presentation in November 2009 in Windhoek, Namibia, Dr. Thomas Michel, states that one of the factors impeding regional agricultural trade is the lack of policy coordination and harmonized regulations. If one factors in the introduction of new GM crops this may be compounded. Eighteen percent of total agricultural exports go to other SADC countries (ranked second to exports to the EU) and 31 % of total agricultural imports come from other SADC countries (ranked first). There have been calls by various stakeholders to harmonise legislation regarding the regulation of GM crops within the Southern African Development Community (SADC). (www.cta.int/en/content/download/4234/46407/file/**Michel**x.pdf). If there is no harmonization within the region it will lead to needless duplication of information generation and artificial trade barriers. Borders within the SADC region are fairly porous which could lead to the movement of GM material between countries and could have detrimental economic implications if events approved in one country start appearing in another country where they are not approved. If these events then inadvertently end up in the exports of that country there could be severe financial repercussions.

Major GM initiatives in South Africa

There are several global initiatives that that are aiming to develop GM crops that have attributes that can address the issues of our time, to include nutritionally fortified sorghum, pest tolerant potatoes, drought tolerant maize and nitrogen efficient crops. These technologies address different crop productivity limitations and each case represents interesting issues for the regulators, the society and the environment. The development of these initiatives locally signal the need for regulatory authorities to strengthen their systems to deal with more potential products, and potential to evaluate traits or events that have not been deregulated elsewhere in the world. Each project poses new challenges depending on the technological approaches, and the species being improved.

Potato Resistant to Potato Tuber Moth

The PTM resistant potato initiative was developed locally by the Agricultural Research Council. A regulatory dossier for the general release of a potato resistant to PTM has been developed in South Africa. A major benefit of this potato is that it gives total protection against PTM. This is especially valuable for small scale potato producers who wish to store potatoes in diffuse light stores. Currently there is no pesticide registered in South Africa that

can be used against PTM in storage. PTM can completely destroy stored potatoes within a month. Despite being shown to be safe, this product was not approved by the EC for general release.

Nutritionally fortified Sorghum: The ABS Project

The ABS project seeks to develop a more nutritious and easily digestible sorghum variety that contains increased levels of essential amino acids, especially lysine, increased levels of pro-vitamins A and more available iron and zinc (http://biosorghum.org/abs_project.php). The success of the Project could improve the health of a target 300 million people who depend on sorghum as a staple food in Africa. This project has faced major challenges as it tries to develop GM sorghum in a region where sorghum is endemic, and regulators are struggling to deal with these issues as regulators around the globe have struggled with similar situations (e.g. GM maize in Mexico).

Water Efficient Maize for Africa

Drought is a major obstacle to maize production in Africa and other regions of the world, and drought tolerance has been recognised as one of the most important targets of crop improvement programs. Identifying ways to mitigate drought risk, stabilise yields, and encourage small-scale farmers to adopt best management practices is fundamental to realising food security and improved livelihoods for the continent. AATF is leading a public-private partnership called Water Efficient Maize for Africa (WEMA) to develop drought-tolerant African maize using conventional breeding, marker-assisted breeding, and biotechnology. This a collaboration between AATF, the international agbiotech giant Monsanto, International Maize and Wheat Improvement Center (CIMMYT) and national agricultural research organisations in Kenya, Mozambique, South Africa, Tanzania and Uganda (http://www.aatf-africa.org/wema).

Nitrogen efficient Crops

In February 2010, it was publicly announced that the Bill and Melinda Gates Foundation will support the **Improved Maize for African Soils Project (IMAS),** which aims to develop maize varieties that are better at capturing the small amount of fertilizer that African farmers can afford, and that use the nitrogen they take up more efficiently to produce grain. Project participants will use cutting-edge biotechnology tools such as molecular markers and transgenic approaches to develop varieties that ultimately yield 30-50% more than currently available varieties, with the same amount of nitrogen fertilizer applied or when grown on poorer soils. The expectation from this initiative is the improvement of food security and

livelihoods in sub-Saharan Africa. The consortium will create and share new maize varieties that use fertilizer more efficiently and help smallholder farmers get higher yields, even where soils are poor and little commercial fertilizer is used. The collaboration is a private and public entity partnership to be led by the International Maize and Wheat Improvement Center (CIMMYT) and other partners include Pioneer Hi-Bred, a DuPont business; the Kenya Agricultural Research Institute (KARI); and the South African Agricultural Research Council (ARC).

Future prospects

South Africa has made major strides in the adoption of GM crops, and the benefits of this technology are already being felt in the economy. This was achieved through the setting up and implementation of a regulatory framework that has facilitated the general release of quite a number of traits in three main crops. The System has also coped with stacked traits, which have been released since 2007. The system faces many challenges, with the regulatory processes getting tighter and slower as it battles to cope with the changing political and economic environment.

Where the early crops that were adopted in South Africa focused on enhancing productivity, the technology has moved from the traditional food, feed and fibre into traditionally non-food utilities to address more complex contemporary health, social and industrial challenges (Chakauya et al., 2006). Thus, research initiatives are focusing on the enhancement of quality of food crops and the production of proteins for therapeutic uses in humans and livestock. These technologies bring on new challenges that even the more advanced of the developing countries are still struggling to cope with. The opportunity presented by these technologies is enormous, but the challenge is to balance the need to adopt such promising technology with caution in dealing with the technology. It is with no doubt that these new applications have brought more sophisticated technical, scientific and social challenges especially for the growing economies of Africa that are still grappling to cope with regulating GMO foods. Unfortunately, there is a possible chance of missing all these opportunities if no proper planning and introspection is done to make operational the splendid regulatory frameworks being developed in the different countries. On the other hand, poorly informed hasty decisions to embrace some of these technologies without proper considerations for the environment and the people might certainly result in disastrous consequences. Regulatory issues are a critical aspect in the adoption of this technology, and even though South Africa has a well established and tested regulatory system, challenges remain.

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