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REGULATION OF AGRICULTURAL GM TECHNOLOGY IN AFRICA

Mobilising Science and Science Academies for Policymaking

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It was formed in response to the need for an Academy of Science consonant with the dawn of democracy in South Africa: activist in its mission of using science for the benefit of society, with a mandate encompassing all fields of scientific enquiry in a seamless way, and including in its ranks the full diversity of South Africa's distinguished scientists.

The Parliament of South Africa passed the Academy of Science of South Africa Act (*Act 67 of 2001*), as amended, and the Act came into force on 15 May 2002. This has made ASSAf the official Academy of Science of South Africa, recognised by government and representing South Africa in the international community of science academies.

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FOREWORD

Agricultural biotechnology, specifically genetic modification (GM) technology, has the potential to contribute to poverty reduction and food security on the African continent. Increased crop productivity and increased adaptation to drought and pests are some of the benefits. Yet Africa has been slow to reap the benefits of GM crops. The main objective of this policymakers' booklet is to provide science-based information that will encourage safe access to GM technology.

It focuses on ways that could improve the efficiency and quality of policy development for GM technology, as well as on building African policymakers' confidence by suggesting effective ways of procuring and using scientific evidence in GM risk analysis. It also focuses on the role of the public; the African national science academies and science-related associations in GM regulatory systems and processes. The key messages are on how this scientific advice can be procured from reputable organisations/institutions such as African national science academies. Using transparent, inclusive institutional mechanisms to engage the public in GM technology regulatory processes are also recommended.

Given their role of providing evidence-based scientific advice to government and increasing public awareness of science, national science academies in Africa are well placed to take up the challenge of providing evidence-based advice on GM crops. The booklet is a guide to African policymakers on how they can procure and use evidence to make informed decisions on the development, introduction, commercialisation and use of agricultural GM technology.

ASSAf acknowledges Professor John Mugabe for compiling this booklet and the many reviewers, whose contributions have added considerable value to the content. The Mauritius Academy of Science and Technology (MAST) is acknowledged for their contribution and for hosting the collaborative workshop. The Global Network of Science Academies (IAP) is thanked for funding this project.

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ACRONYMS

AAS	African Academy of Sciences
AATF	African Agricultural Technology Foundation
ABNE	African Biosafety Network of Expertise
ACGT	African Centre for Gene Technologies
AGERI	Agricultural Genetic Engineering Research Institute
ARC	Agricultural Research Council
ASSAf	Academy of Science of South Africa
AU	African Union
Bt	*Bacillus thuringiensis*
CGIAR	Consultative Group on International Agricultural Research
CSIR	Council for Scientific and Industrial Research
DNA	Deoxyribonucleic acid
EASAC	European Academies Science Advisory Council
EU	European Union
FABI	Forestry and Agricultural Biotechnology Institute (University of Pretoria)
FAO	United Nations Food and Agriculture Organisation
GDP	Gross domestic product
GM	Genetically modified/genetic modification
GMOs	Genetically modified organisms
ha	Hectare
HIV/ AIDS	Human immunodeficiency virus/ Acquired immunodeficiency syndrome
IAP	Global Network of Science Academies
ISAAA	The International Service for the Acquisition of Agri-biotech Applications
INERA	National Agricultural Research Institute (Burkina Faso)
KARI	Kenya Agricultural Research Institute
kg	Kilogram
MAST	Mauritius Academy of Science and Technology
MDG	Millennium Development Goal
NASAC	Network of African Science Academies
NBA	National Biosafety Agency
NEPAD	New Partnership for Africa's Development
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
SASRI	South African Sugarcane Research Institute
UN	United Nations
UNAS	Uganda National Academy of Sciences
UP	University of Pretoria
USA	United States of America

INTRODUCTION

This policymakers' booklet is produced by the Academy of Science of South Africa (ASSAf) as part of the project *"GMOs for African Agriculture: Opportunities and Challenges"*. The project was implemented through ASSAf's Committee on Science for Poverty Alleviation. The project is in its second year of implementation with funding from the Global Network of Science Academies (IAP).

ASSAf has a mandate to give independent and non-biased, evidence-based advice to government/policymakers and the public/society on issues that are of interest to the South African nation and beyond. Prior to compiling this booklet ASSAf, in collaboration with the Mauritius Academy of Science and Technology (MAST), held a joint workshop on policy and institutional challenges to the development, regulation and commercialisation of agricultural GMOs in Africa. The workshop, which took place on 7 June 2011 in Mauritius, was attended by participants and speakers from across the African continent. Participants shared information on the status of GM research and commercialisation activities in the countries of the four African regions (north, south, east and west). They discussed factors that are contributing to the slow rate of commercialising GMOs in Africa and made suggestions for institutional capacity building to improve regulatory systems.

This booklet builds on the discussions and suggestions made at the workshop. It highlights the key opportunities of genetic modification in agriculture, and policy and institutional challenges in regulating the development, introduction and commercialisation of GMOs. The booklet places emphasis on the importance of African policymakers procuring and using credible scientific evidence and expertise from academies in order to make accurate and timely decisions on GM technology to ensure its effective and sustainable utilisation. It also discusses the importance of mobilising science academies and scientific evidence and ensuring public participation in GM technology regulatory processes.

KEY MESSAGES FOR POLICYMAKERS

1. Agricultural biotechnology can help to transform Africa's agriculture, increase food production and enable African communities to adapt to climate change **if African governments establish and use efficient technology regulatory systems where appropriate. Efficient regulatory systems must be predictable; they should promote innovation, as well as the diffusion and utilisation of agricultural biotechnology.**
2. The regulation of agricultural biotechnology, in general, and genetic modification, in particular, **is knowledge intensive and should be based on peer-reviewed evidence obtained from hypothesis-based testing.**
3. African policymakers **should ensure that they procure and use robust evidence-based, peer-reviewed scientific information and advice** when making decisions on the development, introduction, commercialisation and importation of genetically modified organisms (GMOs).
4. African national and regional science **academies are sources of credible and independent scientific expertise and advice** on agricultural biotechnology. Policymakers should seek to engage African academies when making decisions on the regulation of agricultural biotechnology.
5. In addition to science, public participation is necessary to instil confidence among stakeholders about GM technology decision-making. African policymakers **should create and use transparent, as well as inclusive institutional mechanisms to engage the public in GM technology regulatory processes.**
6. **National policies and laws** on agricultural biotechnology can only be successfully and effectively implemented if there is real political will and conviction. Policymakers and regulators should also be able to publicly defend their decisions on GM technology.

CONTEXT: AGRICULTURE AND AFRICAN DEVELOPMENT

Africa is vividly confronted by a paradox: food insecurity in an era of rapid technological advances in agriculture. While the rest of the developing world is purposely engaged in the development and application of modern agricultural biotechnologies, such as GM technology, Africa is held back and continually preoccupied with the old debate on the role and safety of technology in food production and sustainable development.

The mixed response to GM technology by European Union (EU) countries and the negative political sentiment in the EU, Africa's major trade partner, has undoubtedly influenced the political acceptance process in Africa. However, it is important that decision-making in Africa takes account of the local situation and that it is made for Africa.

The continent is exposed to:

- a wide range of scientific applications or techniques to improve crop varieties and livestock production through genetic modification; and
- a pool of scientific knowledge and innovations for conserving biological diversity and addressing the challenges of climate change.

Yet, Africa is failing to effectively harness and use new knowledge and innovations to fight hunger, eliminate malnutrition and achieve higher levels of human development. **More than 25 million people are food insecure and exposed to ecological catastrophes such as drought and floods in Africa.**

Agriculture is Critical to Attaining the MDGs in Africa

The extent to which Africa will attain the United Nations (UN) Millennium Development Goals (MDGs), and the MDG 1 (eradicate poverty and hunger) in particular, is dependent on improvements in agricultural productivity. Agriculture is the foundation of Africa's social, political and economic systems. It is the source of livelihoods, political stability and the growth of national economies. Agriculture provides employment to 65 percent of Africa's population and accounts for at least 30 percent of the gross domestic product (GDP) of the continent. Women constitute at least 50 percent of the labour force in African agriculture. Thus, improvements in agricultural productivity are likely to promote the achievement of MDG 3 (promote gender equality and empower women). The productivity of agriculture will also determine the extent to which other MDGs are attained in Africa.

However, African agriculture is underdeveloped and is not being used adequately to expand human capabilities and create opportunities for relief of poverty. Agriculture in Africa, particularly in sub-Saharan Africa, is rain-fed, largely on a subsistence or small-scale level and produces yields much lower than those achieved in more advanced agricultural systems. It lacks infrastructure and institutional sophistication and is less mechanised when compared to the United States, Europe, Asia and even Latin America. It can be argued that the underdevelopment of the continent's agriculture is one of the primary reasons for the continuing situation of food insecurity and poverty.

In comparison with other regions in the world, agricultural growth has been slow in Africa. For example, the yield gap for cereals between sub-Saharan Africa and other regions has widened over the past two decades or so. "Cereal yields in Africa have grown little and are still at around 1.2 tonnes per hectare (ha), compared to an average yield of some 3 tonnes per hectare in the developing world as a whole. Fertiliser consumption was only 13 kg/ha in sub-Saharan Africa in 2002, compared to 73 kg/ha in the Middle East and North Africa and 190 kg/ha in East Asia and the Pacific."[1]

According to the UN Food and Agriculture Organisation's (FAO) State of Food and Agriculture 2010–2011, sub-Saharan Africa:

- is home to 26 percent of the world's undernourished population;
- has the highest number of countries experiencing food emergences due, in part, to climate extremes such as drought and exacerbated by civil unrest;
- experienced increased food imports during the first half of this decade; and
- is very vulnerable to global food price increases.

The poor performance of the agricultural sector undermines Africa's prospects of attaining the MDGs and sustainable development in general. It also makes the continent more vulnerable to impacts of climate change and global financial crises. The low agricultural productivity is associated with a wide range of factors, including low investments in education, infrastructure, research and development (R&D) and over-reliance on conventional technologies.[2] The application of the best of conventional agricultural technologies can make a significant contribution to improving food security, but on its own will not solve the immense food production challenges that the African continent faces. The expansion of cultivated land through mechanisation and provision

Role of Agriculture in the Attainment of MDGs

"While the linkage with agriculture is particularly strong for the first MDG, or MDG 1 – halving by 2015 the proportion of those suffering from extreme poverty and hunger – all MDGs have direct or indirect linkages with agriculture. Agriculture contributes to MDG 1 through agriculture-led economic growth and through improved nutrition. In low-income countries, economic growth, which enables increased employment and rising wages, is the only means by which the poor will be able to satisfy their needs sustainably. MDG 2, on universal education: A more dynamic agricultural sector will change the assessment of economic returns to educating children, compared to the returns from keeping children out of school to work in household (agricultural) enterprises. Agriculture contributes to MDG 3 directly through the empowerment of women farmers and indirectly through reduction of the time burden on women for domestic tasks. Agriculture contributes to reduced child mortality (MDG 4) indirectly by increasing diversity of food production and making more resources available to manage childhood illnesses, particularly those caused by micronutrient deficiency. Agriculture directly helps improve maternal health (MDG 5) through more diversified food production and higher quality diets, and indirectly through increased incomes and, thus, reduced time burdens on women. Agriculture also directly helps to combat HIV/AIDS, malaria, and other diseases (MDG 6) through higher quality diets, and indirectly by providing additional income that can be devoted to health services and education. Agriculture practices can be both direct causes of and important solutions to environmental degradation (MDG 7). More productive agricultural technologies allow the withdrawal of agriculture from marginal, sensitive environments. Developing a global partnership for development (MDG 8) will help maintain the steady increase in agricultural trade and significant increases in development assistance offered to the agricultural sector, increases that help sustain the benefits from agriculture in the longer term."

Source: www.ifpri.org/publication/agriculture-and-achieving-milliennium-development-goals

of fertilisers can make a positive impact on food security in Africa, but further benefits can be achieved by the application of modern biotechnology methods to plant-improvement programmes, principally for the so-called 'orphan crops' of particular importance to Africa.

The under-representation of the private sector in agriculture in Africa needs attention. In most parts of the world, the private sector is driving 'cutting-edge' R&D in agriculture. In Africa, the opposite is true. African governments need to encourage a positive investment climate for external, as well as internal, private sector participation in agricultural R&D. This can be achieved through the introduction of enabling policies, including a clear regulatory framework and intellectual property protection, that encourage private sector investment.

Key Message for Policymakers

African countries should increase investments in R&D and relevant technological innovations in agriculture.

Increased agricultural production and food security will come through technological innovations, coupled with education, and not from mere provision of traditional farm inputs.

African governments should create a positive investment climate for private sector participation in agricultural R&D.

AGRICULTURAL BIOTECHNOLOGY: GLOBAL TRENDS AND OPPORTUNITIES

Agricultural biotechnology, including genetic marker-assisted conventional plant breeding, and GM technology in particular, holds great promise of helping to transform Africa's agriculture. In much of the world, the application of technology is making it possible to break barriers to increased food production by increasing yields, decreasing crop losses to pests and disease, both pre- and post-harvest, and developing crops that are more able to withstand/tolerate the extremes of climate. New varieties of crops and livestock vaccines are being developed and made available to farmers around the world in unprecedented ways. This technology and its application are:

- science intensive – capabilities in scientific fields, such as molecular biology, biochemistry, physiology and synthetic biology, are critical for successful engagement with and application of the technology; and
- pervasive – the knowledge and techniques can be applied across economic sectors. For example, techniques developed for and applied in crop improvement can also be applied in the conservation of genetic resources and improvement of forests.

GM crops were first used commercially in 1996, and since then have been rapidly adopted by most of the major agriculturally advanced countries in the world. It is "the stable, heritable modification of an organism's genetic makeup via asexual gene transfer, regardless of the origin and nature of the introduced gene."[3] For example, a gene from a common soil bacterium that occurs in nature can be inserted into cotton to produce a variety which confers resistance to insect pests such as the cotton bollworm.

GM technology may also involve modifying a plant's own genes through gene-splicing (i.e. the technology of changing the organism's genetic traits by rearranging specific pieces of its DNA *in vitro*). The introduction of regulatory DNA sequences which control gene expression can, for example, increase or decrease the activity or expression of certain genes already in the organism themselves, thus modifying beneficial agricultural traits in the mature crop.

GM is increasingly based on the application of a growing understanding of how the genetic information found in the plant defines those traits of benefit, with second generation GM crops being developed to address quality, nutrition, processing and value-added traits. This information is derived from a combination of new techniques, particularly genomics, proteomics, metabolomics and bioinformatics, which allow scientists to develop a far more comprehensive image of the metabolic and physiological impacts of an individual genetic trait. A genetically modified organism (GMO) is the product of the process of genetic modification.

Key Message
GM technology makes it possible to develop crops with useful traits when conventional breeding techniques are not able to develop such traits. It offers great potential for enhancing the productivity of crops and food quality by increasing their resistance to biotic and abiotic stresses, improving their post-harvest characteristics and/or enhancing their nutritional composition.

The first GM crop was released for commercial use in the United States of America (USA) in 1996. It was a tomato (called FlavrSavr) that was genetically modified to not ripen on the vine but only once it reached the market, to protect it from post-harvest damage. Since its introduction, the adoption of GM crops has advanced rapidly around the world, particularly in Asia, Latin America and North America. In 2011, the cultivation of these crops reached a total of 160 million ha in 19 developing and 10 developed countries.[4] Almost 17 million farmers, of which 90% are small resource-poor farmers in developing countries, are growing biotech crops. Overall, in 2011, the developing countries' global contribution of biotech crops was almost 50 percent and it is anticipated that they will surpass the industrial countries' hectarage in 2012.[5]

In terms of regional outlook of GM crop cultivation and adoption, in 2011:

- North America: the USA is still the leading producer of GM crops, accounting for 69 million ha (43 percent of global production). Canada is ranked fifth in the world;
- Europe: contrary to commonly held misconceptions, six European Union (EU) countries (Spain, Portugal, Romania, Czech Republic, Poland and Slovakia) cultivated 114 490 ha of Bt maize, a 26 percent increase from 2010;
- Latin and South America: Brazil is ranked second to the USA with Argentina ranked third. Other countries include Paraguay, Mexico, Colombia, Chile, Uruguay and Cuba;
- Asia: China, India, Myanmar, Philippines, Iran and Pakistan cultivated GM crops;
- Africa: Burkina Faso, Egypt and South Africa (with South Africa being the ninth largest producer overall).[5]

Although Burkina Faso, Egypt and South Africa are currently the only African countries that commercially cultivate GM crops, advanced field trials have also been conducted in Kenya, Nigeria, Uganda and Zimbabwe.

GM Traits Targeted

Currently the major agronomic traits targeted through GM are insect resistance and herbicide tolerance. The crops of focus are maize, cotton, soybean and rapeseed/canola. In 2009, these crops accounted for more than 50 percent of all GM crops under commercial cultivation around the world.

Future and Ongoing GM Developments

A growing number of other crops and plants are being tested with various GM traits, including potato, beet, tobacco, rice, barley, wheat, sugarcane and eucalyptus. In addition, a number of previously neglected

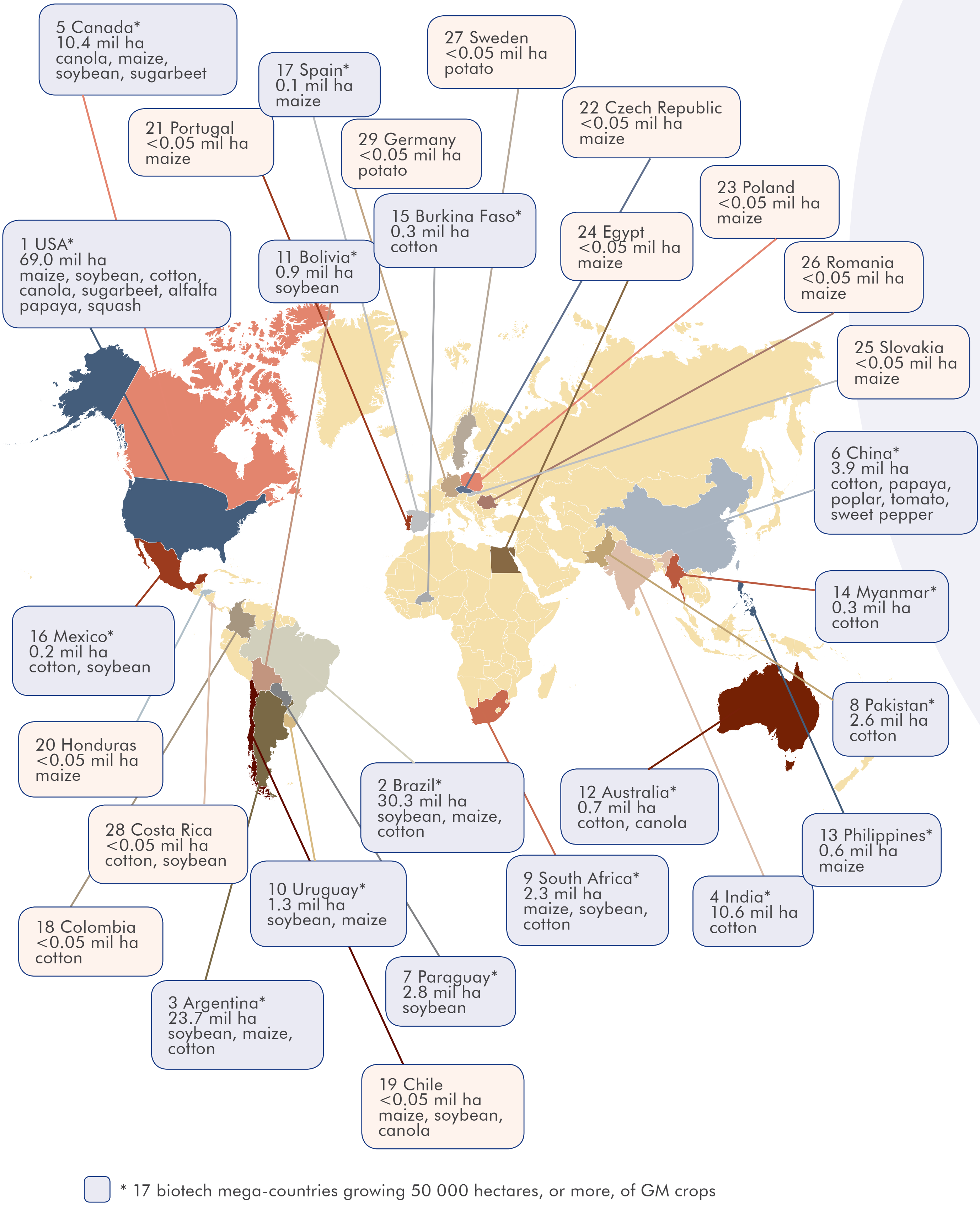

Figure 1: Biotechnology crops' statistics for 2011 (James, 2011)[4]

so-called 'orphan crops', such as cassava, pigeon pea, banana and sweet potato, which are important staples in many African countries, are also being improved by both conventional breeding and GM. Forage crops are also receiving significant attention and several species have already been evaluated in field trials. GM alfalfa has already been commercialised in the USA and Canada.

New lines of GM maize, soybean, cotton and rapeseed are still being developed. By 2015, it is predicted that there will be:

- five lines of GM soybean with herbicide resistance traits compared to three in 2008;
- nine varieties of GM soybean with pest resistance in 2015 compared to one in 2008.[6]

Key Messages for Policymakers

The International Service for the Acquisition of Agri-Biotech Applications (ISAAA) reported that there has been a 94-fold increase in hectarage from 1.7 million ha in 1996 to 160 million ha in 2011. They concluded that this makes biotech crops the fastest adopted crop technology in modern agriculture history.

In the 16-year period (1996–2011), millions of farmers cultivated and re-cultivated over 1.5 billion ha (accumulated) of biotech crops. This indicates that biotech crops provided substantial, sustainable, socio-economic and environmental benefits for these farmers.

Source: ISAAA Brief 43-2011

Farmers' Pragmatism

"Growers around the world are facing challenging economic hardships, trapped somewhere between rising prices for input costs and increasing yields and unpredictable prices for their crops. For most farmers, (...) issues about technical use agreements, patent rights, and multinational corporate politics pale beside the pragmatic concern of producing a crop whose bottom line will not be red. Producers view the environmental and food safety risks of GM crops as small to nonexistent, and see diversification of GM products as the only viable way to increase farm income and profits."

Source: Winston (2002) Travels in the Genetically Modified Zone, p.149. Harvard University Press

African policymakers should also note that farmers are pragmatic. If GM technology can improve quality of life, food production and economic profitability, they can and will adopt it if given the opportunity.

Debate on Risks and Benefits of GM Crops

Over the past two decades or so there has been debate on the impact of biotechnology in general and GMOs in particular. The debate on risks of GMOs has generally focused on environmental, health and socio-economic impacts. In terms of environmental impacts or risks, emphasis has been placed on non-target effects and potential negative impacts on biological diversity. Potential negative impacts on human and animal health focus on possible toxicity and allergenicity effects. There are now numerous studies that show environmental and health benefits of agricultural biotechnology and GM crops.[7]

Environmental

The introduction of GMOs into the environment is perceived that it will destroy indigenous species, lead to the loss of biological diversity or be invasive. However, a multitude of scientific studies have demonstrated that the current, commercially cultivated GMOs should be no more or less invasive than their conventional counterparts. In fact, a number of studies have demonstrated the environmental benefits of these GM crops. For example, a study by Woldenbarger and Phifer (2000) concluded that: "In 1998, 8.2 million fewer pounds of active pesticide ingredient (3.5%) were used on corn, cotton, and soybeans than in 1997 and corresponded to an increase in the adoption of genetically engineered crops."[8] Another study by Qaim (2009) estimated that: "between 1996 and 2006 Bt cotton was responsible for global savings of 128 million kg of pesticide active ingredients, reducing the environmental impact of total cotton pesticides by 25%."[9] According to ISAAA (2011) "the accumulative reduction in pesticides for the period 1996–2010 was estimated at 443 million kilograms (kgs) of active ingredient."

This translates to a 17.9% reduction in the associated environmental impact of the use of pesticide on these crops.[5]

Key Message for Policymakers
The potential environmental risks of GMOs must be evaluated against their demonstrated environmental benefits. Environmental benefits of GMOs are documented, for example, insect-resistant GM crops may decrease the use of agro-chemicals.

Food/feed safety

GM food and feed safety is ensured through a number of international and national regulations and guidelines with the purpose to ensure that GM crops are safe for human and animal consumption. Food/feed safety assessments are comprehensive and include comparative molecular, genetic, metabolic and chemical analyses. They also consider the direct impacts and the possible secondary effects of the introduced GM intervention.[10]

The main objective of these food safety assessments is to give science-based proof that GM foods and feeds are safe. Food safety assessments are typically done on a case-by-case basis as it is not possible to make general conclusions for all possible GM crops.[10]

Current food safety assessments have been proven to be adequate since no adverse effects to human and animal health have been documented since the commercialisation of GM foods more than 15 years ago. GM foods/feeds are vigorously assessed to ensure they are as safe as their conventional counterparts.

Key Message for Policymakers
Health benefits of GM crops include farmers' reduced exposure to insecticides and pesticides, lower pesticide residues in water and food, and lower levels of mycotoxins in maize.

Socio-economic

A number of studies have been conducted to assess the possible socio-economic impacts of the adoption of GM crops.[11] These studies show that if appropriate policy incentives and institutional arrangements are put in place, both small-scale and large-scale farmers adopt GM crops. On the economics of Bt cotton and maize adoption, a study conducted by Qaim (2009) concluded that there are agronomic and economic benefits.[9] According to the ISAAA (2011) a total of 16.7 million farmers grew biotech crops in 2011 and 15 million of these (90%) were small, resource-poor farmers from developing countries. Small farmers are thus economically benefiting disproportionately more.[5]

DEVELOPMENT AND ADOPTION OF GM CROPS IN AFRICA

Since the introduction of GM technology and commercialisation of the first GM crop in the world, few African countries have actively invested in research, technology development and the adoption, as well as commercialisation of GM crops. This is in spite of the declining agricultural production and increasing food insecurity on the continent.

Africa's investment in crop genomics research is insignificant on a global scale. A recent study on funding of basic research in biotechnology demonstrated that South Africa, Africa's leading adopter of GM technology, accounts for an insignificant amount of global total expenditure on GM crop research. South Africa's investment in biotechnology R&D in general and genomics in particular is still low when compared to countries such as China, India, Brazil and South Korea.[12]

GM Crop Research and Field Trials in Africa

Most of the scientific research on GM in agriculture in Africa is conducted in public universities in South Africa, and in some national agricultural research institutes in South Africa, Nigeria, Kenya, Egypt, Uganda and Mauritius. There is also GM crop research being undertaken by international and regional organisations based in Africa. Most of the research activities are documented in recent studies.[13] Below is an overview of some of the GMO research activities in Africa.

South Africa

Table 1 (page 14) provides an overview of GM crop research in South African universities.

GM crop research is conducted by the Agricultural Research Council (ARC). The ARC's Biotechnology Division is conducting research to develop GM potato, soybean, strawberries, apples, sweet potato, *Amaranthus* and *Vigna* varieties that are resistant to drought and high temperatures.

The Council for Scientific and Industrial Research (CSIR) is another key public R&D institution that is engaged in research to develop GM crops. The CSIR, in collaboration with the University of Pretoria (UP), established the African Centre for Gene Technologies (ACGT) – a world-class platform of facilities for genomics research. The Centre is coordinating research on cassava genomics.

The CSIR, in collaboration with the ARC, Africa Harvest, UP and Pioneer Hi-Bred (a private company), has also been conducting research to enhance the nutritional content of sorghum through GM. The research focuses on developing GM sorghum varieties with enhanced essential amino acids (particularly lysine, threonine and tryptophan) vitamins A and E, iron and zinc. Approval for contained trials was granted to the CSIR in 2009. Other CSIR research activities have focused on developing GM tobacco, maize and millet. The South African Sugarcane Research Institute (SASRI) has done work on GM sugarcane.

Table 1: Overview of GM crop research in South African universities

Institution	Overview of research
University of Cape Town, Department of Molecular and Cell Biology	Genetic modification of maize (development of maize streak virus resistant maize, as well as drought tolerant maize), characterisation of novel components of the plant immune system and histidine biosynthesis in plants, and research in genetic diversity and molecular biology of single-stranded DNA viruses
University of Pretoria, Forestry and Agricultural Biotechnology Institute (FABI)	Cereal genomics, forest molecular genetics, molecular plant physiology, comparative genomics, phylogenetic studies linked to diagnostics, and gene discovery linked to disease resistance and drought tolerance of crops
University of the Witwatersrand (Wits), Department of Plant Biotechnology	Mass production of plants using somatic embryogenesis techniques. Somatic embryos are used in both genetic transformation and cryopreservation studies
University of Stellenbosch, Institute for Plant Biotechnology	Understanding of carbohydrate partitioning in plant organs of strawberry, tomato and grapevine; identification of novel genes coding for biopolymer synthetics or modifying enzymes; and understanding of plant growth using proteomic and transcriptomic analysis
University of the Free State	High-throughput analysis of proteins and enzyme assays, including proteome analysis, and the screening of plant extracts for activating activities for specific enzymes. Research on analysis of gene expression microarrays and genomics distribution studies, particularly the relationship between the genomic distribution of specific proteins or post-translational modifications of proteins

Source: Based on a questionnaire sent to 10 universities in South Africa. Responses from the five universities not listed above focused mainly on health biotechnology research

Egypt

The main public R&D institute involved in scientific research on GM crops is the Agricultural Genetic Engineering Research Institute (AGERI). The AGERI has research activities to produce:

- GM melon resistant to viruses;
- GM tomato resistant to tomato yellow leaf curl virus; and
- GM potato resistant to potato leaf roll virus.

Mauritius

GM research in Mauritius is largely concentrated on the development of sugarcane. Although no field trials have been conducted, research has led to the development of sugarcane with herbicide resistance. There is also ongoing research to develop GM sugarcane that is resistant to drought in Mauritius. The lack of field trials is mainly because of the failure to fully promulgate the country's GMO Act of 2004 and enact specific regulations for the implementation of the legislation.

Kenya

Research on GM crops is mainly undertaken by the Kenya Agricultural Research Institute (KARI). KARI is collaborating with international institutes of the Consultative Group on International Agricultural Research (CGIAR) and private companies to undertake research. Most of its work on GM crops is in the form of contained and field trials.

In general, there is less scientific or basic research on GM crops in Africa. Most of the activities focused on applied research with emphasis on field trials. **Table 2** provides an overview of countries that have invested in GM crop field trials.

Adoption of GM Crops in Africa

Using acreage of cultivated GM crops as an indicator of the extent of adoption, South Africa, Burkina Faso and Egypt are the leading adopters of agricultural biotechnology in Africa. In 2011, Egypt had less than 0.1 million ha of Bt maize, Burkina Faso had 0.3 million ha under Bt cotton, and South Africa, 2.3 million ha under GM maize, soybean and cotton.[5]

Table 2: Recorded field trials of GM crops in Africa

Country	GM crop
Burkina Faso	Bt cotton (approved for commercialisation), cowpea (insect resistance) and sorghum (biofortified)
Egypt	Maize, (insect resistance; approved for commercialisation), cotton (salt tolerance), wheat (drought tolerance), potato (viral resistance), cucumber (viral resistance), melon (viral resistance) and tomato (viral resistance)
Kenya	Maize (insect resistance), maize (Striga resistant), maize (drought tolerance), cotton (insect resistance), cassava (viral resistance), sweet potato (viral resistance) and sorghum (biofortified)
Mozambique	Maize (drought tolerance)
Nigeria	Cassava (nutrient enhancement), cowpea (Maruka insect resistance), sorghum (biofortified)
South Africa	Maize (drought tolerance), maize (herbicide tolerance), maize (insect resistance), maize (insect and herbicide tolerance), maize (viral resistance), potato (insect resistance), cotton (insect and herbicide tolerance), soybean (herbicide tolerance), sugarcane (insect and herbicide tolerance), sugarcane (viral resistance, increased yields and alternative products), cassava (biofortified), cassava (modified starch), sorghum (biofortified)
Uganda	Banana (fungal resistance), banana (biofortified), maize (drought tolerance), maize (Striga resistance), Bt cotton (insect resistance), cotton (herbicide tolerance), cassava (viral resistance), cassava (insect resistance) and sweet potato (weevil resistance)
Zimbabwe	Cowpea (insect resistance)

Sources: AU/NEPAD African Biosafety Network of Expertise (ABNE) database; interviews; http://www.nepadbiosafety.net; http://bibliosafety.icgeb.org/

Burkina Faso

In 2008, Burkina Faso approved Bt cotton for commercial cultivation after six years of field trials. In early 2011, Bt cotton was cultivated on about 250 000 ha of land.[14] Based on the successful introduction and adoption of Bt cotton, the National Agricultural Research Institute (INERA) of Burkina Faso and the African Agricultural Technology Foundation (AATF) have started field trials of Bt cowpea. In addition, Burkina Faso's National Biosafety Agency (NBA) is reviewing an application for testing and commercial approval of biofortified sorghum.

South Africa

South Africa has the largest commercial application of GM crops in Africa. The first GM crop field trials started in 1992 and the first approved commercial application was in 1997. In 2011 the acreage under GM crops was estimated at 2.3 million ha.[5] There has since been a total of 13 general release permits with four of them for maize, eight for cotton and one for soybean (**Figure 2**). The GM traits introduced to these crops are either insect resistance, herbicide tolerance or both.[10]

Commodity clearance, where GM grains are imported for food and feed (and not for cultivation), is an important aspect in the trade of GM foods. GM importing countries need regulatory measures in place that deal with approval processes involved in obtaining these clearance commodity permits.[15] South Africa, a couple of years after implementing the GMO Act, introduced commodity clearance for a variety of GM products after safety review.[16] The country now has full approval procedures in place for commodity clearance under the GMO Act and the Act also has procedures for exportation of GM products.

Key Message

Despite the increasing adoption rate and benefits of GM crops, less than fifteen African countries have approved field trials and only three countries have GM crops approved for cultivation and commercial use.

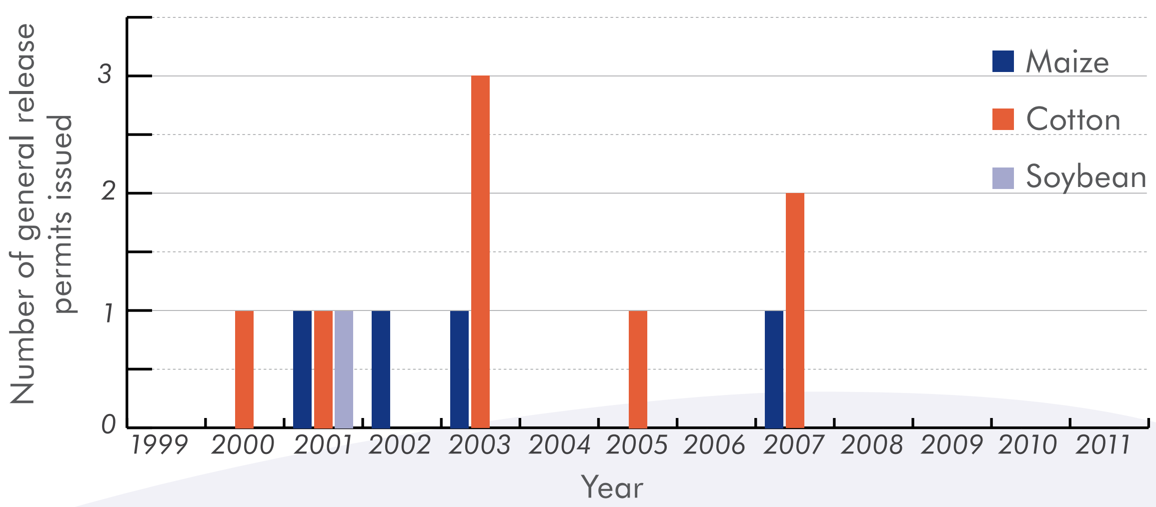

Figure 2: Number of general release permits issued in South Africa *(Biosafety South Africa, 2012)*[10]

Challenges to the Adoption of Agricultural Biotechnology and GM Crops

The low uptake or adoption of agricultural biotechnology in general and GM crops in particular is associated with the following factors:

1. *Inadequate investment in scientific research and promotion of innovation*

   In spite of the documented benefits (i.e. environmental, economic and health), Africa is **not investing adequate resources** to adopt and promote the diffusion of agricultural biotechnology and its GM products. GM crops (for example cassava, potato, maize and cowpea) of high importance in terms of food security are **taking unnecessarily long in the pipeline** of contained laboratory and field trials in some African countries.

2. *Policymakers' indecisiveness*

   The low adoption, diffusion and commercialisation of GM crops in Africa are also associated with **policy uncertainty and the indecisiveness of African leadership**. Many African policymakers are often confronted with opposing views or positions on the role and impacts of GMOs in agriculture. They are often left irresolute after listening to the opposing views of pro-GMO and anti-GMO groups. Their tendency is to either suspend decision-making, or to transfer the responsibility of making decisions on whether to accept or reject the introduction of GMOs into agriculture to relatively junior officers in regulatory offices. In many cases these offices do not have adequate resources to procure the best available science-based advice.

3. *Passive participation of African scientists and science associations*

   In most African countries, scientists with knowledge of GM and information on GM crops are **not actively engaged in raising public awareness** of the benefits of the technology. They are also not actively engaging policymakers to promote informed decision-making. Associations of microbiologists, plant geneticists and science academies are largely at the periphery of the debate on GMOs in Africa.

Key Message for Policymakers
The development and implementation of robust and credible GMO policies and regulatory instruments require both effective scientific advisory systems and the appropriate use of peer-reviewed scientific evidence and advice on risks and benefits by African policymakers. Professional bodies should be actively engaged in the debate and decision-making on GMOs.

In most of Africa, the debate on GMOs is influenced by perceptions and is not based on sound knowledge of risks and/ or benefits. Emotive factors generally influence the debate and little consideration is given to science to inform decision-making. Public leaders and opinion shapers (particularly the media/journalists) have not been well educated on the risks and benefits of biotechnology and GMOs. In some countries, regulators and decision-makers are not trusted by the general public, as many of them are opposed to the introduction and/or commercialisation of GMOs.

In many countries the tendency of policymakers is not to make decisions. This exacerbates the debate, as well as public anxiety and denies the countries opportunities of learning through risk assessment and management.

"Activists propaganda alike overwhelms the public with selected details and slanted interpretations that make it difficult to separate the facts about genetically modified crops from the ideology. The public relations strategy of industry has been to link reassuring lab-coated scientists emphasising the fear of unknown consequences, while also claiming the moral high ground of progress with traditional family farm values. The opposition has consistently nipped at the heels of industry, harping on the same family farm. In the end, it becomes a question of whose lobby is more effective. So far, critics are winning the public's attention while industry has triumphed in the regulatory arena."[17]

The mistrust and policy inaction contribute to lower public acceptance of GMOs and deny many Africans access to food in situations of hunger. When governments fail to ensure that people have access to safe GM food, they are undermining the constitutional rights of citizens.

Key Message for Policymakers
Policymakers should avoid reliance on perceptions of risks and rather deploy expert risk assessment and scientific advice in decision-making. It should be ensured that citizens have access to safe food, and GM technology helps ensure that access.

GOVERNANCE OF AGRICULTURAL BIOTECHNOLOGY IN AFRICA

Overview

A growing number of African countries are putting in place policies, laws and regulations to govern the development, use and commercialisation of GMOs. The state or level of development and application of these instruments varies from country to country. As signatories of the Cartagena Protocol on Biosafety, most of the African countries are required to put in place appropriate and effective legal and administrative structures or measures in order to implement the Protocol effectively. These legal and administrative structures can be built on existing structures, or they can be based on new frameworks.[18] Countries are required to ensure that the development, handling, transport, use, transfer and release of any living modified organisms are done in a way that protects or reduce risks to human health and the biological diversity.[19]

By mid-2009:

- eleven African countries had developed and adopted national biosafety frameworks. These countries are Algeria, Burkina Faso, Egypt, Kenya, Mali, Mauritius, South Africa, Sudan, Togo, Tunisia and Zimbabwe; and
- twelve countries had interim frameworks (Cameroon, Ethiopia, Ghana, Madagascar, Malawi, Mozambique, Namibia, Nigeria, Senegal, Tanzania, Uganda and Zambia).[20]

By late 2011:

- fourteen African countries had full legislation on GMOs (Burkina Faso, Cameroon, Ethiopia, Kenya, Mali, Mozambique, Malawi, Mauritius, Namibia, Senegal, Tanzania Togo, Zambia and Zimbabwe).

Some of the African countries that have not developed and adopted explicit biosafety laws and regulations have implicit instruments, such as national environment regulations, food and drugs laws, and plant quarantine laws. These instruments have provisions that can be invoked to regulate the development, importation and commercialisation of GMOs.

Many of the biosafety laws of African countries have the following shortfalls:

1. They all put too much emphasis on regulating the importation and/or introduction of GMOs developed elsewhere into the country. The laws are either silent on measures to regulate and promote domestic scientific research or just make passing reference to scientific research to locally develop GM crops.
2. They do not have explicit measures for promoting research on biosafety in general and risk assessment in particular.
3. They have provisions on public participation in GM regulatory processes, but do not articulate specific institutional mechanisms for ensuring that the participation takes place.
4. They recognise the importance of science-based decision-making, but are silent on specific measures to be followed to procure and ensure the use of credible scientific evidence.

5. They put emphasis on issues of liability and redress based on an assumption that the technology is to be introduced from outside the country.
6. There is an assumption on the part of most legal frameworks that the process of GM modification is somehow inherently risky and that this is contributing to a perceived need for strict liability. This perception does not reflect current practice and reality.
7. They do not clearly consider the potential benefits of GMOs or the negative aspects of current agricultural practices.

Implementation of Biosafety Regimes: an Overall Assessment

African countries that have enacted laws and adopted regulations on biosafety have different experiences in ensuring efficient and effective implementation of the various provisions of these instruments. They also have different implementation capacities. However, they all face common or similar challenges.

Key common challenges include:

1 **High costs of GM research and development of products, and high costs of ensuring regulatory compliance.** These high costs may be deterring local enterprises or companies from undertaking GM research and commercialisation.

2 **Limited capacity to assess and determine the nature, as well as range, of uncertainties about potential benefits and risks of GMOs.** Most of the countries do not possess expertise in technology assessment and appraisal of risks.

3 **Limited capacity of national biosafety authorities and legal frameworks to effectively engage the public in informed decision-making.** In most African countries biosafety offices have not established institutional mechanisms for informed public participation in GM decision-making. This is despite the national laws having provisions requiring public participation.

SCIENCE AND THE ROLE OF NATIONAL ACADEMIES IN DECISION-MAKING

African policymakers and regulators are increasingly required to make complex decisions on the development, introduction, import, export and diffusion of GMOs in agriculture. As stated earlier, most of the time they have to make these decisions in the face of crisis and without access to evidence-based analysis on the impacts of GMOs.

They are confronted by strong pressures from pro-GMO and anti-GMO activists who wish to influence decision-making. Under these circumstances, African policymakers and regulators are still expected to make robust decisions in legitimate and efficient ways.

In many African countries, policymakers are not constitutionally or legally obliged to base their decisions on scientific evidence of the impacts of GMOs. They also do not have mechanisms, including mandatory guidelines, for the procurement and use of scientific advice. Institutional arrangements for decision-making on GMOs are characterised by:

- absence of independent scientific advisory councils or panels whose members are actively engaged in the science of biotechnology and research on biosafety;
- absence of scientific advisory offices in key bodies such as presidencies, prime ministers' offices and even ministries such as trade and industry, agriculture;
- inconsistencies in and discontinuity of policy processes, often decisions are made under conditions of crisis;

- limited public participation in and ownership of regulatory processes;
- limited public awareness of genetic modification and GMOs;
- relatively low funding for and weak scientific capacities in national regulatory agencies; and
- lack of mandatory guidelines for the collection, review and use of scientific advice.

Key Message for Policymakers

If procured and used well, science provides the means to legitimate and efficient decision-making on GMOs. It is the foundation for evidence-based, non-partisan and consistent policies on GMOs.

National academies of science can play critical roles in the promotion of efficient GM regulation and innovation. They can be the main sources of independent credible scientific expertise and evidence for decision-making. However, as stated earlier, most African academies are not actively engaged in the provision of scientific evidence for and advice on the regulation of GMOs.

There are 17 African national academies of science: Cameroon, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Mauritius, Morocco, Mozambique, Nigeria, Senegal, South Africa, Sudan, Tanzania, Uganda, Zambia and Zimbabwe. There is one regional academy, the African Academy of Sciences (AAS), and a regional network of academies, the Network of African Science Academies (NASAC). Only two national academies have been involved in GMO policymaking, biosafety and regulatory processes in Africa.

National Academies involved in Biosafety Activities

The Academy of Science of South Africa (ASSAf):

- Established a Standing Committee on Biosafety and Biosecurity to investigate mechanisms to regulate the conduct of safe science in South Africa; to raise the awareness of scientists about impacts of technology; and to assess the capacity of national laboratories to implement biosafety measures.

The Uganda National Academy of Sciences (UNAS):

- After the approval of the National Biotechnology and Biosafety Policy by Cabinet in 2008, UNAS convened a multidisciplinary committee of experts to clarify the overlap of biosafety and biosecurity. This was done in an effort to better position government officials as they weigh the pros and cons of government intervention in laboratories and the kinds of regulatory frameworks that might be implemented to ensure safe and secure labs while minimising undue burdens.
- In 2010, UNAS released a report, *The Scope of Biosafety and Biosecurity in Uganda: Policy Recommendations for the Control of Associated Risks*. This report helped to provide conceptual clarity on differences between biosafety and biosecurity. It informed the national biosafety bill.

In other regions and countries of the world, science academies are actively engaged in research and regulatory activities on GM crops and GM in general. For example, in China the Chinese Academy of Sciences not only funds research on GM crops, but also has its own research activities. It is a very influential actor in the country's GM regulatory system. Nearly all members of the scientific panels for biosafety are also members of the Academy. The Academy has also established specific policy institutes that are sources of evidence-based advice to the government. One of the institutes is the Centre for Agricultural Policy which undertakes research on socio-economic impacts of biotechnology.

In Europe, the European Academies Science Advisory Council (EASAC) has been instrumental in producing studies that demonstrate benefits of GM in general and GM crops. For example, in 2003 they launched a study on the contributions of genomics research and its advantages compared to conventional crop breeding techniques.[21] The EASAC is considered an authoritative source of advice, despite European politicians' reluctance to openly promote GM crop adoption because of strong opposition to GM by deep ecology movements.

Key Message for Policymakers
African policymakers should contribute to the strengthening of national and regional science academies to allow them to effectively participate in GM research and regulatory processes.

IMPROVING GMO POLICYMAKING IN AFRICA

Summary of Issues and Key Messages for Policymakers

There are many stakeholders with many different interests involved in the debate and decision-making on GMOs. These include farmers, multinational companies, politicians, scientists, regulators, religious groups, environmentalists, and activists from different professional backgrounds and social groups. Managing the different interests and expectations is one of the challenges of GMO decision-making. In addition to the complexity associated with the many diverse stakeholders:

- GMO decision-making is laden with many scientific, ethical, social and economic issues. The science of genetic engineering and scientific issues associated with risk assessment and management are also complex. Different societal groups have different ethical considerations based on religion and culture; and
- the locus of decision-making is diffused. In most countries, decision-making is spread across the institutional terrain, involving different ministries e.g. agriculture, environment, trade and commerce, industry, and science and technology. These ministries often compete for authority, resources and even public recognition. Each seeks to be the locus of decision-making authority.

Because of the above factors or considerations, policymaking on GMO issues should be guided by the following principles:

- GMOs are not a homogenous group or category of products. Each GMO is specific in content, application and impact. Each GM crop or product should be evaluated independently within a consistent set of applied standards and regulations;
- decision-making on GMOs should be participatory, trans-organisational, transparent, have a multidisciplinary approach that encompasses natural sciences, social sciences and humanities, where appropriate;
- decision-making should be flexible and done on a case-by-case basis allowing for revision of decisions as and when new credible evidence or information is available; and
- an ability to adjust regulatory frameworks and guidelines in the light of new evidence should be regarded as a strength rather than a weakness.

In most African countries the credibility, in terms of robustness and legitimacy, of executive or government decisions on GMOs is often questioned because of the absence of independent scientific advice or input into decision-making. Government departments or national biosafety authorities responsible for regulating the development, introduction and commercialisation of GMOs tend to rely on their in-house experts and/ or scientific advisory committees that are constituted without informed public input and peer reference.[1]

Key Messages for African National Academies of Science

The African national academies of science can:

- be instrumental in supporting governments in general and national biosafety authorities to identify and appoint the best available experts to serve on advisory committees and panels; and
- engage in activities and processes that raise public awareness of and confidence in biotechnology in general and GMOs in particular. At the moment the academies are not playing these roles, at least not actively and effectively.

Academies should:

1. **Establish an inter-academies' programme on agricultural biotechnology.** They should design and implement a programme on biotechnology, with emphasis on the following aspects:
   - networking and supporting African scientists who are engaged in cutting-edge research on genetic modification and risk assessment;
   - monitoring global trends in the science of genetic modification and related technological developments;
   - informing the public and policymakers of the scientific and technological advances through newsletters and other media platforms, and this should be done through proper strategic plans for information flow and dissemination;
   - interpreting the integrity and safety implications or lack thereof of studies as they get published; and
   - conducting review studies on the diffusion of biotechnology and GMOs in Africa.
2. **Help in building public awareness of and confidence** (through the availability of credible information) in genetic modification for improved agriculture and food security. The African public is poorly informed on issues concerning the science and impacts of biotechnology in general and genetic engineering in particular. The academies should contribute to the raising of public awareness through:
   - ensuring school curricula adequately deal with the topic of biotechnology to educate the next generation of scientists, technology developers, risk assessors and regulators;
   - producing popular readers on genetic engineering and GMOs, organising public consensus building workshops, organising training workshops for journalists and other activities that will help better communicate information on the science of genetic engineering and GMOs;
   - designing and delivering of public participation processes that improve public policies on GMOs and agriculture, providing the public access to information from scientists, giving scientists information from the public, and allowing careful consideration of alternatives.
3. **Support the establishment of databases or databanks of experts and relevant scientific research activities.** They can support policymakers to be aware of and use the best available experts and sources of scientific evidence by developing databanks or databases of experts and research activities and then disseminating this information to national biosafety authorities and policymakers.
4. **Establish links with other academies outside of Africa,** especially with countries that have interests in the development and deployment of GM crops. Also, to use these links to share information and experience.

CONCLUSIONS

It is clear that there is an urgent need to mobilise and use scientific advice from all reputable sources in GM technology decision-making in Africa. In addition, effective and informed public participation will ensure that these decisions are more inclusive and widely accepted. It has been shown that while African countries are exposed to GM technologies and products, they are not effectively harnessing these to solve problems of food production. The leadership of African policymakers and scientists is urgently needed to promote technological innovation and the adoption of GM crops in order to increase agricultural production and enhance prospects of food security on the continent.

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